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REPORT OF

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THE ILLINOIS STATE BOARD OF HEALTH,

JAMES A. EGAN, M. D.,
Secretary.

Please acknowledge receipt.

This report was compiled in 1902. Its publication has been delayed until the conclusion of the testimony in the suit brought by the State of Missouri, in the Supreme Court of the United States, against the Sanitary District of Chicago, on account of alleged pollution of the waters of the Mississippi river.

AND THE SANITARY CONDITIONS OF THE WATER SUPPLIES
OF THE

Cities of Chicago and St. Louis

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ILLINOIS STATE BOARD OF HEALTH

REPORT OF

SANITARY INVESTIGATIONS

OF THE

Illinois, Mississippi and Missouri Rivers

WITH RELATION TO THE EFFECT OF THE SEWAGE OF THE

City of Chicago

AND THE SANITARY CONDITIONS OF THE WATER SUPPLIES OF THE

Cities of Chicago and St. Louis

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Observations on the Sewerage Systems and Water Supplies of the Cities of Chicago and St. Louis and the Sanitary Investigations of the Illinois, Mississippi and Missouri Rivers.

By JAMES A. EGAN, M. D.,

SECRETARY.

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OBSERVATIONS ON THE SEWERAGE SYSTEMS AND WATER SUPPLIES OF THE CITIES OF CHICAGO AND ST. LOUIS, AND THE SANITARY INVESTIGATIONS OF THE ILLINOIS, MISSISSIPPI AND MISSOURI RIVERS,

By JAMES A. EGAN, M. D.,

SECRETARY.

What shall be the effect of the Chicago Drainage Canal upon the water supply of the city of Chicago, which is drawn from Lake Michigan, and upon the water supply of the city of St. Louis, which is drawn from the Mississippi River, is the sanitary problem which apparently gives most concern to these two great cities, and through these cities Illinois and Missouri are interested and involved.

From the time the city of Chicago first began to develop into a trading post of some importance, the citizens have had to rely upon Lake Michigan for water for domestic use. In the early days the water was distributed throughout the city by water carriers, who would fill their water carts from the lake with buckets and distribute the water to the citizens. About fifty years ago the first water works system for distributing water by means of pipes was constructed in Chicago, and from that time the water supply system has been developed until today it represents millions of dollars of investment, hundreds of miles of distributing mains, and supplies water to about two million people, or more than one-third of the population of the state of Illinois. The water supply is still taken from Lake Michigan, but instead of being drawn from near the shore as formerly, it is now taken through tunnels which extend from two miles to four miles under the bottom of the lake to where the intake cribs have been located. These tunnels have been built under the lake at great cost for the purpose of securing pure water from Lake Michigan, but with only partial success.

Very soon after the introduction of a water supply system the necessity of a public sewerege system became apparent to the citizens of Chicago. The natural and only outlet for sewage and surface drainage was into Lake Michigan, either direct, or by first draining into the Chicago River, which flowed through the heart of the city and into the lake. In the early days, the Lake Michigan water was pure and wholesome, even near the shores, but as population increased and the amount of drainage and sewage also increased, the pollution of the waters near the shore occurred at first and finally the effect of the sewage reached far beyond the water works intakes. It became apparent to the health authorities of Chicago over thirty years ago that the sewage of that city must be diverted from Lake Michigan as a means of protecting the purity of the city water supply.* The Illinois and Michigan Canal, which was built to furnish steamboat navigation between Lake Michi-

* See Report of Sanitary Investigations of the Illinois River and Its Tributaries, Illinois State Board of Health, 1901.

gan and the Illinois River, was looked to as a possible means of diverting the sewage, and the level between Bridgeport and Lockport was lowered so as to allow of a gravity flow from Lake Michigan through the Chicago River and the canal into the DesPlaines River at Lockport. For a few years this gave relief but the sewage of Chicago increased rapidly and by reason of the large industries centered about the stock yards, the gravity flow of the Illinois and Michigan Canal was insufficient to take all of the Chicago sewage and prevent the flow of sewage through the Chicago River into Lake Michigan. When this condition again menaced the city water supply, a pumping plant was established at Bridgeport in the city of Chicago, which pumped the water from the Chicago River into the Illinois and Michigan Canal, thereby increasing the flow in the canal to such an extent that substantial relief was temporaily secured. It was apparent, however, that the Illinois and Michigan Canal would soon be inadequate under any conditions to carry the sewage of Chicago and prevent its entrance into Lake Michigan. In 1886 a Sewage Commission was appointed which reported in favor of a drainage canal, much larger than the old Illinois and Michigan Canal, which should be constructed so as to connect the Chicago River with the Des Plaines at such a level that a gravity flow could be maintained sufficient to carry away all the Chicago sewage with enough lake water to dilute such sewage so that it would not be a menace to the inhabitants of the Illinois Valley. Acting upon the report and suggestions of this Commission, the Sanitary District of Chicago was organized and the main drainage channel was completed and opened for service on the 17th day of January, 1900, since which time it has been in continuous use.

Prior to the construction of the Drainage Canal the sewers of the city of Chicago had been constructed with their outlets either directly into Lake Michigan or into the Chicago River, according to location and topography. With the drainage canal in operation, the flow of the Chicago River is permanently changed, so that instead of flowing into Lake Michigan, it now flows from Lake Michigan carrying a large quantity of Lake Michigan water through the Chicago River and the main Drainage Channel into the Des Plaines River at Lockport, so that all the sewage which discharges into the Chicago River is carried away from the lake. It became necessary that the sewers discharging into the lake should be intercepted or reversed and plans have been prepared by the city and the works are now under construction which will intercept the sewage, heretofore going into the Lake, and discharge the same into the Chicago River principally by way of the 39th Street and Lawrence avenue conduits. A more detailed description of the water supply, sewerage system and the Chicago River will follow.

The Illinois River has a total water shed or drainage basin of about 27,000 square miles, a small portion of which is in southeastern Wisconsin and another portion in northwestern Indiana. The Illinois River is formed by the confluence of the Des Plaines and the Kankakee about 40 miles southwest from Chicago. From this point it continues in a southwesterly direction through the State of Illinois until it reaches the Mississippi River. The Mississippi and Missouri Rivers drain nearly all of the territory west of the basin of the Great Lakes and east of the Rocky Mountains in the United States. The city of St. Louis is located upon the west bank of the Mississippi

River and takes its water supply from that river at the point known as Chain of Rocks which is about 7 miles below the mouth of the Missouri River. The Illinois River empties into the Mississippi River about 25 miles above the mouth of the Missouri River. The city of St. Louis discharges its sewage into the Mississippi River at various points all below its water works intake. The water of the Missouri River, flowing along the west shore and mingling with the Mississppi, contributes very largely to the quality of the water as it is found at the water works intake at Chain of Rocks. The Illinois has a very much smaller drainage area than the Missouri; the entire drainage area of the Illinois being within the central and northern portion of Illinois and extending thirty or forty miles into Indiana and Wisconsin. The Illinois River brings with it the flow of the sanitary canal of the city of Chicago and receives the sewage of other cities located upon its banks and upon the banks of its tributaries in the State of Illinois. The territory drained by the Mississippi River above its confluence with the Illinois, has several times the area of the territory drained by the Illinois and the area drained by the Missouri is greater than both. Into the Mississippi and Missouri Rivers, the sewage of all the cities located upon their banks and upon the banks of their tributaries, is discharged. At Omaha and Kansas City, on the Missouri River especially, are stock yards and packing industries which discharge quantities of organic matter into the river. The similar industries at Chicago are among the chief contributors of organic matter to the waters passing through the Chicago Sanitary Canal, so that the origin of organic matter found in the Missouri and the Illinois rivers is quite similar, viz drainage from agricultural lands, cities, and much the same kind of manufacturing industries.

A brief description of the St. Louis water works will follow.

The Engineer of the Board, Mr. Jacob A. Harman of Peoria, has prepared two maps which are herewith attached; one showing the state of Illinois and the Illinois water shed From this map the relation of Chicago to St. Louis and the point of entrance of the Illinois and Missouri Rivers into the Mississippi River will be noted. The other map shows the city of Chicago, the Sanitary District of Chicago and vicinity, the location of the water works, intake cribs, tunnels, pumping stations, the Illinois and Michigan Canal and the main drainage channel. The main drainage channel and the intercepting sewers also are shown upon this map and are printed in red. These two maps will show the relation of Chicago drainage to the Chicago water supply and the St. Louis water supply. These maps are to be found at the end of this report.

To show the relation of the principal tributaries of the Illinois River, the junction of the Illinois River with the Mississippi River and the St. Louis water works intake, the following chart has been prepared, representing the distances by scale.

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RECTILINEAR DIAGRAM
DRAINAGE ROUTE
CHICAGO TO ST. LOUIS
JULY, 1903
JACOB A. HARMAN ENG'R.

Scale of Miles
0 20 40 60 80 100 120 140 160 180 200 220 240 260 280 300 320 340 360

ILLINOIS RIVER

Chicago River.
Drainage Canal.
Des Plaines River.
Mississippi River.

Lake Michigan.
Roby Street.
Controlling Works, Lockport.
Joliet.
Kankakee and Des Plaines Rivers.
Ottawa, Fox River.
La Salle, Vermilion River.
Henry Dam.
Peoria.
Pekin.
Mackinaw River.
Copperas Creek Dam.
Havana, Spoon River.
Sangamon River.
Beardstown.
La Grange Dam.
Kampsville Dam.
Mouth of Illinois River.
Mouth of Missouri River
Chain of Rocks, St Louis Water Works Intake.

CHICAGO CITY WATER SUPPLY.

The city of Chicago takes nearly all its water supply from Lake Michigan, through tunnels at four different points. In addition to the water received from the tunnels at these four points, the Rogers Park Water Company supplies that portion of Chicago which was originally the village of Rogers Park through a 16-inch intake pipe extending 1,200 feet into the lake.

Norwood Park is supplied with water from an artesian well. Washington Heights was originally supplied with water from an artesian well, but the flow from the well has decreased until it is very small and part of the water pumped at this station now is supplied from the Sixty-eighth street pumping station through the distribution mains.

The lake tunnels, which furnish Chicago with its principal supply of water, are designated as follows: The Lake View tunnel, six feet in diameter, connecting with the Lake View crib two miles from the shore; the Chicago Avenue tunnels, four in number, one ten feet in diameter extending to the Carter H. Harrison crib two and one-half miles from shore, two seven feet and one five feet in diameter, extending to the two-mile crib, which is two miles from shore; the Fourteenth Street tunnel, being two six-foot tunnels joining about two miles from shore, thence continuing an eight-foot tunnel to the four-mile crib, which is four miles from shore; the Sixty-eighth Street tunnel, seven feet in diameter, extending to the Sixty-eighth Street crib, two miles from shore.

Intake Cribs.—There are five cribs as indicated, viz.: The Lake View crib, out from the Lake View pumping station at Montrose Avenue; the Carter H. Harrison crib and the two-mile crib, out from the Chicago Avenue pumping station; the four-mile crib, out from the Fourteenth Street pumping station; and the Sixty-eighth Street crib, out from the Sixty-eighth Street pumping station. The plans of the Water Department of the city of Chicago contemplate extending the tunnels now connecting with the two-mile crib out to the Carter H. Harrison crib and the abandonment of the two-mile crib, which will reduce the number of cribs to four and remove the intake for a large portion of the city's water supply one-half mile further into the lake.

Lake Tunnels —The first tunnel was constructed at Chicago Avenue and was five feet in diameter, being completed March 25th, 1867. A seven-foot tunnel parallel to the first was completed July 12th, 1874. These tunnels were each two miles in length, connecting with the two-mile crib. The other tunnels have been built and some of them extended, from time to time, until the present. These tunnels have a combined capacity of 415,000,000 gallons of water per twenty-four hours. The average amount of water pumped daily during the months of June, July and August, 1900, was 327,000,000 gallons.

Pumping Stations.—Besides the Rogers Park, Norwood Park and Washington Heights pumping stations, which supply only small isolated districts, there are eight principal pumping stations connected with the lake tunnels above described. These stations are designated and located as follows: *Lake View pumping station*, near the lake shore on Montrose Avenue, taking its water supply from the Lake View crib; *Chicago Avenue pumping station*, located on the lake shore at Chicago Avenue, taking its water supply from the

two-mile crib, also having a six-foot supply connection with the ten-foot tunnel from the Carter H. Harrison crib; the *Fourteenth Street pumping station*, located on the lake shore at Fourteenth street, taking its water supply from the four mile crib; the *Sixty-eighth Street pumping station*, located on the lake shore at Sixty-eighth street, taking its water supply from the Sixty-eighth Street crib; the *Harrison Street pumping station*, located on Harrison street near South Halstead street, supplied by land and lake tunnels connecting with both the two-mile crib and the four-mile crib; the *West pumping station*, located at Twenty-second street and Ashland Avenue, being supplied by land tunnels connecting with both the two-mile crib and the four-mile crib; the *Central Park Avenue pumping station*, located on Central Park avenue near Twelfth street, being supplied by land and lake tunnels connecting with the Carter H. Harrison crib; the *Springfield Avenue pumping station*, located on Springfield Avenue near Courtland street, being supplied by land and lake tunnels connecting with the Carter H. Harrison crib. The capacities of the pumping stations are as follows, viz.:

STATION.	Gallons per 24 hours.
Lake View	45,000,000
Chicago Avenue	99,000,000
Fourteenth Street	84,000,000
Sixty-eighth Street	82,000,000
Harrison Street	36,000,000
West	60,000,000
Central Park Avenue	60,000,000
Springfield Avenue	60,000,000
Norwood Park	1,000,000
Rogers Park	2,500,000
Washington Heights	2,500,000

Land Tunnels —The lake tunnels, extending from the intake cribs to the pumping stations located upon the shore of Lake Michigan, have been described above. In addition to these there are land tunnels connecting the pumping stations which are not located upon the lake shore, with the lake tunnels. A ten-foot land tunnel, connecting with the Carter H. Harrison lake tunnel, extends southwesterly under the city to a point in the vicinity of Green street and Kenzie street, where it divides into two six-foot tunnels, one leading northwesterly to the *Springfield Avenue pumping station* and the other southwesterly to the *Central Park Avenue pumping station.*

A seven-foot land tunnel starts from the shore end of the three tunnels leading to the two-mile crib at Chicago Avenue, extends southwesterly under the city to the *Harrison Street pumping station*, thence continuing on its course to the *West pumping station.*

A seven-foot land tunnel also extends from the shore end of the four-mile crib continuing in a westerly direction under the city to the *Harrison Street pumping station.*

Water Distribution Mains.—From each of the eight pumping stations described, water mains of large dimensions radiate throughout the city. The system of water mains is cross-connected so that the entire system of mains can be filled from any one of the pumping stations. Owing, however, to the consumption of water in the vicinity of each station, the water pumped

from any one station will generally cover a certain district, the boundary of which will vary slightly from time to time.

CHICAGO RIVER.

The Chicago River drains the surface water from a strip of territory extending from Eighty-seventh Street, which is the south boundary of the Sanitary District of Chicago, north to a point opposite the north line of Waukegan; a district from north to south of about 45 miles. The width of this water shed from Eighth-seventh Street to the north limits of the city of Evanston is approximately nine miles. From Evanston north to Waukegan, the width diminishes and the east line of the water shed recedes more or less gradually from the west shore of Lake Michigan until it is three miles west of the lake at Waukegan.

The total area of this water shed is 270 square miles; 98 square miles of which is tributary to the south branch and 172 square miles tributary to the north branch. Under existing conditions the Chicago River must furnish an outlet for all storm water and natural drainage for this territory.

East of the drainage basin of the Chicago River, there are certain tracts of land which drain directly into Lake Michigan; from the north line of the city of Evanston to Waukegan this land varies in width from one to three miles. From North Avenue to the north limits of Evanston, the strip of land tributary to Lake Michigan is not over one mile wide and contains an area of 9 square miles; 4.7 square miles of which is in the Sanitary District of Chicago and 4.3 square miles in Rogers Park and Evanston; Rogers Park now being within the City of Chicago, but not within the Sanitary District of Chicago.

South of the mouth of the Chicago River and extending to the water shed of the Calumet River, is an area of 31.5 square miles draining directly into Lake Michigan, of which 25.5 square miles is in the Sanitary District of Chicago and 6 square miles south of the Sanitary District of Chicago, all being within the limits of the city of Chicago.

The Chicago River has two principal tributaries known as the north branch and south branch. The north branch receives the natural drainage and sewage of 172 square miles of territory. The Fullerton conduit was put into operation January 9, 1880. This conduit is 12 ft. in diameter and extends along Fullerton Avenue from Lake Michigan to the north branch of the river where a pumping station is located. This pumping station is to deliver Lake Michigan water into the north branch of the river for diluting the sewage and flushing the stream. The natural outlet of the north branch is through the main river into Lake Michigan.

The south branch of the Chicago River drains 98 square miles of Chicago territory and has one tributary known as the south fork of the south branch; the south fork leads to the Stock Yards slip, located on Thirty-ninth Street, which receives the sewage from the Stock Yards and packing industries. The south fork extends west as far as Western Avenue.

The Chicago River, since the opening of the main drainage channel which connects with the south fork at Robey Street, is made to flow westward into the Des Plaines River, instead of into Lake Michigan. The flow from the north branch, instead of flowing out through the main river into Lake

Michigan, joins with a stream of Lake Michigan water flowing through the main river and through the south branch to the main drainage channel. The south fork of the south branch joins the south branch near Bridgeport where pumping works are located which lift the water from the south fork into the Summit level of the Illinois and Michigan Canal, whence it flows westward. Prior to the opening of the main drainage channel, the pumping works were operated by the city of Chicago for the purpose of discharging sewage into the Des Plaines River by way of the Illinois and Michigan Canal and thus prevent the contamination of Lake Michigan, but the capacity of the pumping works and canal being too small, led to the construction of the main drainage channel. Since the opening of the main drainage channel the pumping works at Bridgeport have been operated to maintain a stage of water sufficient for navagation in the Summit level in the Illinois and Michigan Canal.

All of the flow from the south fork which is not pumped at Bridgeport into the Illinois and Michigan Canal flows into the south branch of the Chicago River, thence to the main drainage channel.

On August 19, 1900, the flow of the south fork of the south branch was less than the amount of water being pumped by the Bridgeport pumps, so that a part of the water being pumped was supplied from the south branch. This condition will generally prevail when the Bridgeport pumps are in operation, except during freshets.

When the intercepting sewerage systems are completed the Lawrence Avenue conduit, 16 feet in diameter, will be used to supply Lake Michigan water to dilute the water of the north branch, and the 39th Street conduit, 20 feet in diameter, will be used to supply Lake Michigan water to dilute the water of the Stock Yards slip and the south fork of the south branch of the Chicago River.

The volume of water which will pass through the Lawrence Avenue and 39th Street conduits, is a part of the amount required by the Sanitary District law.

CHICAGO INTERCEPTING SEWER SYSTEM.

At the present time the city of Chicago is constructing a system of intercepting sewers for the purpose of diverting the sewage which now flows into Lake Michigan to the Chicago River and Drainage Canal.

During 1898 two sewerage systems which originally emptied into Lake Michigan were "reversed" and now empty into the Chicago River. These are known as the Twelfth-street and Twenty-first street sewers, and connect with all of the sewers south of the mouth of the Chicago River as far as Thirty-first street. From Thirty-first street south to Seventy-third street all of the sewage east of State street now flows into Lake Michigan, sewer outlets being located at the following streets, viz.: Thirty-fifth street, Forty-first street, Forty-second street, Forty-fourth street, Fifty-first street, Fifty-third street, Fifty-fifth street, Sixty-first street and Seventy-third street. From Seventy-third street south to Eighty-seventh street, no sewerage system has been constructed. From Eighty-seventh street south to the Calumet, a district extending west about a mile from Lake Michigan, has been drained into the Calumet River.

The intercepting sewer system on the south side, which is now under construction, includes a twenty-foot conduit on Thirty-ninth street extending from Lake Michigan to the Stock Yards slip on the south fork of the south branch of the Chicago River. Into this conduit intercepting sewers located along the lake shore from Thirty-fifth street to Fifty-first street, thence extending southward to Seventy-ninth street, are being constructed. These intercepting sewers, when completed, will divert to the Drainage Canal all of the sewage that is now flowing into Lake Michigan between Thirty-fifth street and Seventy-third street and also the sewage from the proposed sewer system which will drain the territory lying between Seventy-third street and Eighty-seventh street, Eighty-seventh street being the south boundary line of the Sanitary District of Chicago. When these works have been completed all of the sewage of Chicago, south of the mouth of the Chicago River as far as Eighty-seventh street, will be diverted from Lake Michigan, and the Calumet District will still discharge its sewage by way of the Calumet River into Lake Michigan within about three miles of the Sixty-eighth street intake crib. North of the Chicago River, as far as Lincoln Park, the sewage now flows into the Chicago River. From Lincoln Park to the north city limits, being also the south limit of the city of Evanston, the sewage of about 250,000 population flows into Lake Michigan at frequent intervals from about 22 separate sewer outlets. To intercept this sewage and divert it from Lake Michigan, the intercepting sewerage system of the north side contemplates the construction of a sixteen-foot conduit in Lawrence Avenue extending from Lake Michigan to the north branch of the Chicago River. Leading into this conduit will be main intercepting sewers extending along the lake shore to be connected with all of the sewers now discharging into Lake Michigan.

Since the opening of the Drainage Canal and the changes made in the Twelfth street and Twenty-second street sewers, the sewage still discharging into the lake between Eighty-seventh street and the north city limits is equivalent to the sewage of about 500,000 population. This sewage will be diverted to the canal by the completion of the north side and south side intercepting sewer system and the Lawrence avenue and Thirty-ninth street conduits now under construction.

In addition to receiving the sewage from the intercepting sewers, the Lawrence avenue conduit is being constructed for the purpose of furnishing lake water with which to flush and dilute the north branch of the Chicago River. The pumping station will be located at the river end of the conduit. The Thirty-ninth street conduit is to be used in a similar way to flush the Stock Yards slip on the south fork of the south branch of the Chicago River; the pumping station will be located at the lake end of this conduit.

POPULATION AND AREAS.

The total area lying south of the Chicago River in which sewers are being completed, and now discharging its sewage directly into Lake Michigan, which area is bounded on the north by Thirty-first street, on the south by Seventy-fifth street, on the west by State street, is 7,983 acres and had an estimated population, by school census in 1898, of 162,208. The area of the district having no sewerage system, from which sewage will be discharged

into the intercepting sewerage system, and located between Seventy-fifth street and Eighty-seventh street, is 728 acres and had an estimated population of 18,399. North of the Chicago River there is a sewer system area of 3,419 acres draining into Lake Michigan, which has a population of 25,400. The sewage from this entire area will be diverted fr m Lake Michigan by the completion of the intercepting sewerage system of the Lawrence avenue conduit.

ST. LOUIS WATER SUPPLY.

The city of St. Louis obtains its water supply from the Mississippi River about 1500 feet from the Missouri shore at the point known as Chain of Rocks. Chain of Rocks is seven (7) miles below the confluence of the Mississippi and Missouri Rivers and ten (1) miles above the Eads Bridge. The city of St. Louis occupies the right bank of the Mississippi River, from a point one (1) mile above Chain of Rocks, down stream for a distance of nineteen (19) miles. For a distance of four (4) or five (5) miles down stream from Chain of Rocks, the valley on the Missouri side, is very narrow and is used for gardening and farming. This portion of the city was annexed so as to include the site of the water works improvements. The main part of the city lies along the west shore of the river and extends back several miles from the river, beginning about (5) miles south of Chain of Rocks, thence south to the southern limits.

Bissell's Point is located six and one half (6½) miles below Chain of Rocks and is the location at which the city formerly took its water supply from the Mississippi River. In 1895, the new pumping station and settling basins being completed at Chain of Rocks, the river supply at Bissell's Point was discontinued and since that time all the water has been supplied to the city from Chain of Rocks. When the water works pumping station was located at Bissell's Point it was far above the city and beyond any source of local contamination from sewage, but the growth of the city made it necessary to change the location of the pumping station from Bissell's Point to a point further up stream to avoid direct contamination of the city's water supply by its own sewage.

The Mississippi River water at Chain of Rocks is always turbid. When the waters of the Missouri River are high the turbidity is very much greater than under other conditions. High waters in the Mississippi produce a considerable amount of turbidity for short periods of time. The large amount of turbidity always present in the Mississippi River at Chain of Rocks is due, in most part, to the water from the Missouri River. This turbidity is caused by suspended organic and iorganic matter, the greater part of which is very minute particles of earth. This turbidity does not in itself render the water unsafe for drink, but makes it very objectionable for all domestic and manufacturing purposes.

In order to reduce the turbidity and purify the water supply, large reservoirs have been constructed into which the water is pumped and allowed to stand for a number of hours or days and part of the suspended matter settles to the bottom of the reservoir, after which the more or less clarified water is drawn off and distributed to the city through the water mains. A

number of these reservoirs or "settling basins," as they are called, were constructed at Bissell's Point and used in connection with the pumping station, when the water supply was taken from the river there. Another set of settling basins was constructed at Chain of Rocks which are now used for that purpose. Large quantities of mud are deposited each year in the bottom of the settling basins and this mud is removed at intervals by scrapers or by other means. The clarification and purification effected by the settling process has never been entirely satisfactory; as the water, though very much improved over its condition when pumped from the river, is neither clear nor pure. For a great many years the city of St. Louis has been considering the question of pure water, and its officials have from time to time, devised and recommended plans and schemes for the further purification of the city water supply. These plans and schemes generally have contemplated the filtration of the city water supply in addition to the sedimentation now being accomplished. As early as 1865 the city directed its City Engineer, Mr. James P. Kirkwood, to make a trip to Europe and there sutdy the methods of filtration in use and report back to the city his observations and plans for filtering the St. Louis water supply. Since that time the subject of filtration has been pressed with more or less vigor, but without action being taken. Within the last two years a commission of consulting engineers has studied and made extensive reports upon the improvement of the city's water supply. This commission, by its several members, made two reports; one recommending that a new water supply be established, to be taken from streams about fifty (50) miles southwest of St. Louis, as this section of the state is sparsely settled and not adapted to agriculture. The other report recommends filtration of the present water supply in addition to the sedimentation.

There is no doubt but that some time in the future, some plan will be carried out to provide the city with a pure water supply, either by filtration or otherwise.

The population of St. Louis in 1900 was 575,000. The growth of the city has been moderate but steady during the past four decades and its geographical location is such that it will continue to increase in population and commercial importance so that the demands upon the city water supply will also increase. The daily consumption of water during the year 1900 was approximately 63,000,000 gallons and the estimated amount for 1910 is 110, 000,000 gallons. The demands therefore, of the city are large now with prospects of greater demand in the immediate as well as distant future.

Chemical and bacteriological examinations which, are reported in the following pages, were undertaken for the purpose of continuing further the study of the condition of the Illinois River where it enters the Mississippi and of comparing the condition of the Illinois River water with that of the Mississippi River just above the entrance of the Illinois and of the Missouri River where it enters the Mississippi. During the years 1899 and 1900 chemical and bacteriological examinations and tests were made under the direction of this Board and published in its "Report of Sanitary Investigations of the Illinois River and Its Tributaries." Reference is now made to that report for the results of those investigations and for further comparisons with the investigations herein reported.

Public and official attention has been directed particularly to the effect (on the waters of the Illinois and Mississippi Rivers) of the discharge of Chicago sewage, diluted with Lake Michigan water, through the main drainage channel from Chicago. That channel now probably receives three-fourths of all the sewage of the city. During the years 1900 and 1901 the flow through the main drainage channel was about 250,000 cubic feet per minute, consisting of Chicago sewage diluted with Lake Michigan water. That volume of water is much in excess of the ordinary low water flow of the Illinois. The chemical and bacteriological conditions of the Illinois River at various points throughout its course were studied and compared in the previous report, above referred to, during the years 1899 and 1900, being the first year preceding and the first year after the opening of the main drainage channel. The results of those examinations demonstrated that for the year immediately before and the year immediately after the opening of the drainage channel, the water in the Illinois River at its mouth was practically free from sewage contamination and better chemically and bacteriologically from a sanitary standpoint than the water coming from its tributaries.

For the investigations of 1899 and 1900 samples of Mississippi River water above the mouth of the Illinois were also taken for analyses and comparison with the results obtained by the analyses of the Illinois River water. About 25 or 26 miles below the mouth of the Illinois, the Missouri River enters the Mississippi, the mouth of the Missouri River being about eight or nine miles above the Chain of Rocks, where the St. Louis water works intake is located. The St. Louis intake being near the Missouri shore. it is generally recognized and conceded that a large part of the water which is drawn through the intake and distributed to the inhabitants of St. Louis is Missouri River water as distinguished from Mississippi River and Illinois River water. There may be times when there is an extensive co-mingling of the three rivers, but there are certainly times when none but Missouri River water reaches the intake.

The location of the St. Louis intake, with reference to the junction of the Illinois and the Missouri and the Missouri and the Mississippi Rivers, leads to the conclusion that an examination of the chemical and bacteriological conditions of the water of these three rivers near their respective confluences would be of much service in throwing light upon the subject as to the source of greatest pollution of the St Louis water supply. Arrangements were made for taking samples of water during the autumn months of 1901 and the spring months of 1902 from each of those rivers for the purpose of such comparison and the full report of these analyses, as made by Dr. John H. Long, chemist, and Dr. F. Robert Zeit, bacteriologist, are published herewith.

The following short table of chemical analyses has been compiled from chemists' reports herewith published and previous reports before referred to. This table shows the averages of the chemical analyses through the summer and autumn seasons for three years, namely, 1899, 1900 and 1901 of the Illinois and Mississippi River waters and for the same seasons for 1901 of the Missouri River water.

TABLE OF AVERAGE CHEMICAL ANALYSES OF SAMPLES OF WATER DURING SUMMER AND AUTUMN FROM THE MISSISSIPPI RIVER ABOVE THE MOUTH OF THE ILLINOIS AT GRAFTON, ILLINOIS RIVER AT GRAFTON, AND MISSOURI RIVER IMMEDIATELY ABOVE ITS MOUTH:

	PARTS PER MILLION.						
	MISSISSIPPI RIVER.			ILLINOIS RIVER.			MISSOURI RIVER.
	1899.	1900.	1901.	1899.	1900.	1901.	1901.
Total solids	273.0	347.0	183.0	332.0	331.0	261.	1294.
Loss on ignition, filtered	.....	40.	33.	.....	47.	36.	29.
Loss on ignition, unfiltered	.....	53.	36.	.....	57.0	40.	82.
Chlorine	1.77	2.	1.88	17.50	10.6	16.4	14.9
Oxygen, absorbed, filtered	6 82	7.08	6.53	4.65	4.82	3.21	3.17
Oxygen, absorbed, unfiltered	8.52	11.73	7.84	5.61	5.85	4.31	10.28
Free ammonia	0.080	0.07	0.07	0.247	0.07	0.238	0.10
Albuminoid ammonia	0.443	0.51	0.39	0.455	0.36	0.413	0.60
Nitrogen in nitrates	0.03	0.03	0.08	0.59	0.87	1.042	0.13
Nitrogen in nitrites	0.001	0.02	0.001	0.044	0.03	0.034	.0006
Organic ammonia, Kjeldahl	.....	1.49	0.74	.....	1.13	0.81	1.61

An inspection of this table shows that the condition of the waters of the Mississippi and the Illinois have not materially changed during three seasons. The Illinois shows the largest amount of chlorine and nitrates. This unusual amount of chlorine is an evidence of a large amount of sewage which has been received by the Illinois and its tributaries, but the analyses for organic matter and bacteriological examination give little evidence of this sewage pollution, except in the harmless chlorine and nitrates. Comparing by total solids there is no great difference between the Mississippi and Illinois; by oxygen consumed the Mississippi shows a greater amount of organic matter than the Illinois.

The analyses of the Missouri River water, which are only for one year, show that the condition of the water of that river is in some respects more like the Illinois than the Mississippi. It is especially noticeable that the amount of chlorine is high, almost as high as the Illinois.

Bacterially the Mississippi and Missouri are very much alike and the Illinois shows a better and safer sanitary condition than either Special attention is called to the report of Prof. Zeit, on pathogenic and sewage bacteria, herewith published. Not only the chemical examination above referred to and heretofore published, but these and the former bacteriologial examinations show that the water of the Illinois River contains less sewage matter than either the Mississippi or Missouri. Whatever the amount of sewage the Illinois River may have received at its head and from its tributaries throughout its course, by reason of its slow flow the time required for its waters to reach the Mississippi has been seized upon by nature's purifying agents, water bacteria, and the sewage has been largely reduced to harmless form. The bacteria, so numerous in the Illinois above Morris and again immediately below Peoria and Pekin, have materially diminished and are more frequently found in the Mississippi and Missouri River waters than in the water of the Illinois, where these rivers merge into the Mississippi.

As previously stated, public attention has been directed to the Chicago sewage as the chief, if not the only, source of sewage pollution to be serious-

ly considered in connection with the St. Louis water supply. Little regard is apparently paid to the many cities of importance located upon the Illinois and its tributaries, the Mississippi and the Missouri, all of which contribute more or less to the pollution of the streams on which they are located. On the Illinois there is a noted example of excessive pollution, other than Chicago, at Peoria and Pekin. Chemical and bacteriological examinations dur- 1899 and 1900 show the condition of the water of the Illinois River to be better at the "narrows" or Averyville, immediately above Peoria, than at any other station throughout its course, all traces of the Chicago sewage excepting nitrates and chlorine having disappeared. At Peoria large quantities of sewage are introduced into the river and the process of purification, from that point to the mouth of the river, does not seem to be as rapid as in the upper reaches of the stream. The purification in the first 40 miles above Peoria is especially pronounced.

A detailed study of the amount of sewage pollution in the upper Mississippi and Missouri Rivers has not been made. It is well known, that on the Missouri River especially, there are numerous cities of great commercial importance which discharge their sewage into the river. At Omaha and Kansas City especially are large stock yards and packing industries which contribute much to the pollution of the Missouri River. It is also a well known fact that the Mississippi and Missouri Rivers both have very much more rapid current than the Illinois River and that, measured by the time it takes the water of these rivers to reach the Chain of Rocks, St. Paul and Minneapolis, on the Mississippi, and Omaha or, perhaps Sioux City, on the Missouri, are as near to the St. Louis water works intake as Chicago. Kansas City, St. Joseph, Rock Island, Davenport and Moline, Muscatine, Des Moines, Keokuk, Quincy and many other smaller cities discharge their sewage past the St. Louis water works intake when it is several days newer and more charged with pathogenic bacteria than Chicago sewage.

The question as to the self purification (may it not be better expressed "natural purification"?) of streams, probably becomes the all important one. Scientific investigations have demonstrated that under favorable conditions, the foulest stream will become pure by natural processes. This cannot occur, however, if at frequent intervals along its course more sewage is added to keep up the supply of organic waste material. The Illinois River more nearly meets the requirements as to length, time and other conditions for bacteriological purification of the sewage which it receives than either of the other streams. This is fully demonstaated by the fact that twice in its course it is grossly polluted—viz., from Chicago and at Peoria and Pekin—and twice, also viz; above Peoria and again before it empties into the Mississippi, it is so purified by natural processes, that it is of better quality than any of its tributaries, and only traces of the enormous double pollution remain.

It seems proper to state the following general conclusions as the result of the sanitary investigations which have been made under the direction of the Illinois State Board of Health prior to and after the opening of the Chicago Drainage Canal:

The water supply of the city of St. Louis as taken from the Mississippi River at Chain of Rocks is not materially nor injuriously affected by the flow from the Illinois River, for the reason that the Illinois River

water, as it enters the Mississippi, shows less sewage contamination than the water of the Missouri River at its mouth, and is practically as good as the Mississippi River water itself, so that if the Illinois River could be so changed that it would empty into the Mississippi below the water works intake of the city of St. Louis there would be no material change in the condition of the St. Louis water supply. Furthermore, the city of St. Louis cannot and does not hope or expect to have a satisfactory or safe water supply from either the Mississippi or Missouri Rivers without filtering such water.

The effect of the increased flow of water from Lake Michigan through the Chicago Drainage Canal has improved the condition of the water in the Des Plaines and Illinois, especially under low water conditions. Prior to the opening of the Drainage Canal the amount of sewage discharged into the Des Plaines through the Illinois and Michigan Canal was much greater than the natural flow of the Des Plaines at low water and even greater than the natural flow of the Illinois River as far as Peoria. The dilution which has been effected by the larger discharge of lake water through the new Drainage Canal is much greater than existed prior to its opening. The washings into the streams from the farms, pastures, barn yards and small villages, not to mention the large cities and manufacturing industries, contribute an amount of organic matter equivalent to a considerable sewage pollution and taken altogether the natural low water flow of the Illinois River would probably show a greater pollution than the flow of the Chicago Drainage Canal in its present condition.

When the Sanitary District of Chicago shall have completed proper extensions* to the main drainage canal which will carry off the sewage of the Evanston and Calumet regions; when the city of Chicago shall have completed her intercepting sewer systems which are designed to divert her sewage from Lake Michigan, the water supply of Chicago will no longer be subject to material pollution, and the inhabitants of that great city will no longer be compelled to pay tribute to the springs of neighboring states or to the producers of distilled water or the manufacturers of filters.

At easy access they will find a boundless supply of good water, not one which vies in chemical purity with the products of famous springs, but a wholesome water which contains no impurities prejudicial to health.

With no pollution at her doors, the city of Chicago need have no fears as to the quality of her water supply. Beyond the reach of sewage contamination from the shore, the water of Lake Michigan is known to be pure. Contaminated though the lake may be by sewage from neighboring states, the probability of this contamination reaching the intakes of the Chicago water supply is too remote to cause serious apprehension.

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* A law enlarging the corporate limits of the Sanitary District of Chicago became in force July 1, 1903.

CHEMICAL AND BACTERIAL EXAMINATIONS

OF THE

Waters of the Illinois, Missouri and Mississippi Rivers

BY JOHN H. LONG, Sc. D.

UNDER THE DIRECTION OF

THE ILLINOIS STATE BOARD OF HEALTH.

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THE ILLINOIS STATE BOARD OF HEALTH.

DR. JAMES A. EGAN, *Secretary Illinois State Board of Health,*

DEAR SIR:—In two previous reports submitted to your Board the rate of sewage oxidation in the Illinois river under widely different conditions was discussed. In the first of these reports the nature of the water before the opening of the Drainage Canal, as shown by numerous analyses, was disclosed, while in the second and longer one the effect of the larger flow from the new canal was especially considered. Some time after the completion of the investigation detailed in the second report the trustees of the Sanitary District of Chicago decided to decrease the flow of water in the canal from the 300,000 cubic feet per minute standard to a volume nearer 250,000 cubic feet, and as this lowered dilution might not be without effect on the rate of oxidation in the Illinois a new chemical and bacterial examination was thought necessary. Accordingly, by direction of your Board, I undertook this third series of experiments, but on lines differing materially from those of the former investigations. Practically, we are concerned mainly with these important questions: What is the condition of the water at the mouth of the Illinois river; how does it compare with the Mississippi above the junction or with the Missouri above its mouth; what is the condition now compared with that of the period just before the opening of the Drainage Canal?

In answering these questions we are not much concerned with the rate or velocity of oxidation, but mainly with final conditions, as these are admittedly the points in dispute. From this standpoint, therefore, it appeared unnecessary to undertake the further study of waters at a number of places above the mouth of the Illinois or the Missouri, but a closer study was decided upon for these localities. Because of the peculiar questions involved in the final discussion it was thought advisable to pay particular attention to the nature of the Missouri river water just above its mouth. Since the conclusion of the former investigations the importance of this line of inquiry has been clearly recognized.

In September of last year, 1901, a tour of inspection was made of the river region around Grafton and below Alton, and points for water collection were selected. For the Illinois and Mississippi these were the same as

the former examinations, with the same collector. In each case a location was chosen far enough up stream to secure water unmixed with that from the other stream. For the Missouri river water a collector was secured from the Illinois side, on account of the more direct shipping service possible, and this man was instructed as to the proper method of collecting, packing and forwarding samples. The place of collection, a short distance above the mouth of the Missouri, was reached by rowing from the Illinois side. In all cases the samples were collected in the afternoon and shipped so as to reach Chicago and be delivered to me before noon of the day following. The small bottles for bacterial examination were well packed in ice, and it may be said here that they always reached me in good condition.

METHODS OF EXAMINATION.

These have been fully explained in the earlier reports and need not be repeated. I have been assisted in the work by Mr. Frank Wright, Mr. Charles W. Brown and Mr. William Johnson. The identification of pathogenic bacteria was undertaken by Professor Robert Zeit, who will make a special report on this part of the work.

RESULTS OF THE EXAMINATIONS.

The tables below give the results obtained in the tests. These are divided into two series. In the first waters were collected from near the end of September to about the middle of December, that is until the formation of ice began. In the second series the examinations were resumed as soon as possible after the breaking up of the ice in the Spring of 1902. The object here was to secure water under the conditions least favorable to bacterial oxidation.

TABLE I—*Mouth of*

Date.		Color.	Odor.	Sediment.	Temperature.		Solids.			Loss on Ignition.	
					Water	Air	In solution	In suspension	Total	Not filtered	Filtered
1901.											
Sept.	23	Light turbid	None	Sandy	64°	76°	280	18	298	42	38
"	24	"	"	"	68°	82°	224	50	274	38	32
"	26	Light	"	"	71°	84°	212	62	274	40	32
"	30	Yellow	"	"	69°	80°	232	60	292	34	30
Oct.	1	"	Good	"	70°	80°	220	52	272	40	28
"	3	"	"	"	66°	60°	232	60	292	48	42
"	7	"	None	"	60°	71°	256	52	308	40	38
"	8	"	"	"	63°	66°	254	50	304	40	36
"	10	"	"	"	64°	72°	248	60	308	30	28
"	14	"	"	"	58°	50°	244	49	293	61	68
"	15	"	"	"	58°	62°	232	40	272	38	38
"	17	"	"	"	57°	55°	228	42	270	32	30
"	21	"	"	"	58°	64°	226	62	288	36	36
"	22	"	"	"	58°	68°	240	38	278	34	32
"	28	"	"	"	60°	64°	212	58	270	36	22
"	29	"	"	"	61°	72°	232	36	268	24	16
"	31	"	"	"	62°	62°	200	46	246	20	16
Nov.	4	"	"	"	54°	44°	268	12	280	46	36
"	5	"	"	"	52°	43°	216	40	256	36	36
"	7	"	"	"	49°	48°	242	10	252	28	26
"	11	"	"	"	49°	64°	224	38	262	34	26
"	12	"	"	"	49°	45°	230	42	272	28	24
"	14	"	"	"	47°	55°	236	16	252	44	32
"	18	"	"	"	42°	42°	226	22	248	42	30
"	19	"	"	"	39°	43°	226	16	242	44	42
"	21	"	"	"	40°	50°	222	24	246	34	26
"	25	"	"	None	41°	45°	238	4	242	30	30
"	26	"	"	Little	40°	48°	214	14	228	36	36
"	28	"	"	"	41°	44°	228	20	248	50	46
"	29	"	"	None	40°	50°	232	4	236	48	36
Dec.	2	"	"	"	43°	40°	222	10	232	54	50
"	3	"	"	"	42°	38°	228	2	230	50	48
"	5	"	"	Little	38°	32°	230	18	248	54	54
"	6	"	"	None	38°	35°	220	2	222	32	32
"	9	"	"	"	37°	34°	216	12	228	42	42
"	10	"	"	"	36°	38°	226	2	228	64	62
"	11	"	"	Sandy	37°	34°	150	70	220	36	34
"	12	"	"	"	37°	40°	217	0.3	220	44	44
		Means			52°	55°	229	32	261	40	36

Illinois River—Grafton.

Chlorine.	Oxygen absorbed.		Ammonia.		Nitrogen.		Organic ammonia by Kjeldahl process.	Colonies—per cc.	Fermentation.		Coagulation of milk 38°.	Indol produced.
	Not filtered.	Filtered.	Free.	Albuminoid.	In nitrate.	In nitrite.			½ cc.	1 cc.		
16.0	4.80	4.32	0.19	0.29	1.20	0.040	0.43	2,800	No gas	No gas	24 hours	
16.7	4.64	4.00	0.14	0.24	1.40	0.040	0.63	700	"	35%	Very slow	
17.0	4.00	3.52	0.16	0.21	0.40	0.040	0.63	250	80%	No gas	24 hours	
16.7	2.88	2.56	0.15	0.32	0.06	0.035	0.63	1,050	No gas	"	"	
17.7	3.04	2.72	0.12	0.36	1.60	0.040	0.43	Liquefied.	"	"	"	No
17.7	4.48	3.84	0.16	0.27	1.00	0.035	0.63	400	20%	5%		"
19.1	4.80	4.16	0.15	0.28	0.96	0.080	0.82	400	No gas	No gas	Slow	"
19.5	4.32	4.00	0.12	0.27	1.20	0.060	0 72	250				"
22.3	3.84	2.88	0.09	0.27	0.64	0.050	0.72		No gas	No gas		"
17.4	3.36	2.56	0.11	0.40	0.96	0.030	0.52	1,250	"	"	Slow	"
17.8	3.04	2.88	0.12	0.25	1.44	0.030	0.52	850	80%	10%	24 hours	"
18.1	4.16	3.04	0.11	0.25	1.40	0.030	0 62	20,200	10%	10%	"	"
18.1	4.48	3.36	0.19	0.45	1.52	0.030	0.72	13,100	60%	20%	"	"
18.0	4.32	2.72	0.17	0.39	0.96	0.050	0.72	400	No gas	60%	20 hours	"
18.1	4.32	2.88	0.10	0.33	1.60	0.250	0.62	Liquefied.	"	No gas	Slow	"
19.2	4.48	3.20	0.08	0.40	1.00	0.015		2,050	50%	80%	Very slow	"
17.0	4.32	2.32	0.05	0.40	1.20	0.015	1.26	450	No gas	No gas	Slow	"
17.0	2.40	2.08	0.13	0 39	1.20	0.020	0.62	4,100	"	"	Rapid	"
16.7	3.68	1.92	0.10	0.44	1.40	0.030	0.62	1,150	"	5%	"	"
17.0	6.08	5.60	0.08	0.38	1.00	0.020	0.82	100	10%	No gas	24 hours	"
17.0	8.00	2.72	0.10	0.48	1.00	0.025	0.70	400	No gas	"	Very slow	"
16 0	4.00	3.04	0.11	0.44	0.60	0.025	0.60	150	"	80%	Slow	"
16.7	3.36	2.72	0.08	0.54	1.12	None.	1.40	450	20%	No gas	24 hours	"
17.7	5.12	3.68	0.09	0.71	0.80	0.020	1.40	150	No gas	"	Slow	"
16.0	5.12	3.36	0.14	0.70	1.12	0.025	1.40	1,050	"	10%	12 hours	"
14.9	4.64	3.36	0.13	0.69	0.56	None.	0.70	Liquefied.	"	No gas	None	"
13.5	4.80	3.68	0.22	0.78	0.64	0.020	1.00	1,050	"	85%	Very slow	"
13.5	4 96	3.36	0.19	0.53	0.48	0.020	1.10	25,800	"		None	"
16.3	4.96	3.52	0.19	0.51	1.12	0.020	1.10	Liquefied.	"		12 hours	"
12.8	4.32	4.00	0.30	0.38	1.12	0.030	1.10	"	"	No gas	Very slow	"
16.0	3.84	2.40	0.31	0.46	0.88	0.030	1.10			"	None	"
6.4	3.68	3.20	0.28	0.40	1.20	0.020	1.10			"	Slow	"
15.3	4.64	3.36	0.56	0.42	1.12	0.020	1.12	Liquefied.	No gas	25%	Rapid	"
17.0	4.16	3.36	0.74	0.41	1.44	0.030	0.72	"	"	25%	"	"
15.6	4.64	2.56	0.71	0.44	1.12	0.015	0.92	"	"	60%	"	"
14.2	3.84	3.68	0.79	0.46	0.80	0.015	0.84		20%	25%	20 hours	"
11.7	4.96	3.04	0.81	0.32	1.12	0.020	0.52		20%	40%	"	"
13.5	3.36	2.32	0.76	0.41	1.20	0.025	0.92		15%	50%	"	Yes
16.4	4.31	3.21	0.238	0.413	1.042	0.034	0.81					

TABLE II.—*Mississippi River*—

Date.		Color.	Odor.	Sediment.	Temperature.		Solids.			Loss on Ignition.	
					Water	Air	In solution	In suspension	Total	Not filtered	Filtered
1901.											
Sept.	23	Yellow	None	Sandy	61°	76°	160	40	200	38	36
"	24	Light turbid	"	"	64°	82°	156	44	200	40	40
"	26	Yellow	"	"	68°	84°	150	32	182	34	34
"	30	"	"	"	67°	80°	150	52	202	24	22
Oct.	1	"	"	"	68°	80°	140	58	198	34	30
"	3	"	"	"	65°	60°	150	72	222	36	32
"	7	"	"	"	58°	71°	136	78	214	24	22
"	8	"	"	"	61°	66°	144	74	218	40	32
"	10	"	"	"	62°	72°	152	96	248	32	28
"	14	"	"	"	56°	50°	152	58	210	34	32
"	15	"	"	"	56°	52°	148	44	192	40	38
"	17	"	"	"	55°	55°	158	50	208	26	24
"	21	"	"	"	56°	64°	140	52	192	38	32
"	22	"	"	"	57°	68°	132	66	198	40	36
"	28	"	"	"	58°	64°	144	68	212	46	38
"	29										
"	31	"	"	"	60°	62°	136	58	194	30	28
Nov.	4	"	"	"	52°	44°	144	52	196	44	36
"	5	"	"	"	50°	43°	140	48	188	40	36
"	7	"	"	"	47°	48°	132	50	182	30	28
"	11	"	"	"	47°	64°	142	30	172	34	30
"	12	"	"	"	47°	45°	140	36	176	30	28
"	14	"	"	"	45°	45°	156	18	174	36	34
"	18	"	"	"	38°	42°	148	18	166	34	32
"	19	"	"	Little	37°	43°	148	20	168	30	28
"	21	"	"	"	38°	50°	154	26	180	24	22
"	25	"	"	None	39°	45°	152	2	154	32	30
"	28	"	"	"	38°	48°	136	2	138	32	30
"	28	"	"	"	40°	44°	136	10	146	44	42
"	29	"	"	Little	39°	50°	140	26	166	36	34
Dec.	2	"	"	"	41°	40°	142	16	158	40	38
"	5	"	"	None	36°	32°	150	2	152	46	44
"	6	"	"	"	36°	35°	148	6	154	46	44
"	9	"	"	"	35°	34°	144	8	152	46	44
"	10	"	"	Little	35°	38°	148	20	168	48	46
"	11	"	"	"	36°	34°	140	22	162	52	50
"	12	"	"	"	36°	40°	136	16	152	40	38
		Means			50°	54°	145	38	183	36	33

Grafton—Above Mouth of Illinois.

Chlorine.	Oxygen absorbed.		Ammonia.		Nitrogen.		Organic ammonia by Kjeldahl process.	Colonies—per cc.	Fermentation.		Coagulation of milk.	Indol produced.
	Not filtered.	Filtered.	Free.	Albuminoid.	In nitrate.	In nitrite.			1/10 cc.	1 cc.		
								Plate				
1.80	7.68	6.88	0.06	0.42	0 16	None.	0.63	Liquefied.	No gas	No gas	18 hours	
2.13	9.12	8.32	0.04	0.41	0.12	"	0.93	1,700	"	90%	24 hours	
2.50	8.00	7.36	0.09	0.35	0.12	"	0.63	450	50%	No gas	"	
2.13	7.68	5.60	0.08	0.44	1.20	"	0.53	1,750	No gas	"	"	
2.13	7.04	6.40	0.09	0.42	0.14	Trace	0.63		"	"		No
2.50	8.16	6.88	0.08	0.45	0.12	None.	0.93	Liquefied.	"	10%		"
2.13	8.32	6.56	0.07	0.46	0.06	"	0.72	350	"	No gas		"
1.80	6.56	6.56	0.07	0.40	0.08	"	0.92	300				
1.80	8.00	4.96	0.07	0.41	0.08	Trace	0.72		10%	10%	Slow	No
1.80	7.20	5.92	0.08	0.37	None.	"	0 52	700	10%	No gas	"	"
1.80	6.56	6.24	0.06	0.34	0.08	"	0.72	450	No gas	80%	24 hours	"
2.13	7.36	3.20	0.08	0.37	0.06	None.	0.72	5,200	"	No gas	Slow	"
1.42	11.68	9.28	0.11	0.46	0.08	"	0.92	2,100	30%	5%	24 hours	"
1.42	7.68	7.04	0.08	0.44	Trace	"	0.92	550	No gas	60%	20 hours	"
1.78	9.76	8.48	0.09	0.43	None.	0.100	1.02	400	"	60%	"	"
								Liquefied.	5%	50%	"	"
1.78	9.60	8.16	0.10	0.48	0.10	None.	0.62	750	No gas	No gas	24 hours	"
2.13	10.40	5.12	0.10	0.42	0.10	"	0.62	700	"	50%	Rapid	"
2.13	9.92	9.60	0.11	0.45	None.	"	0.82	300	10%	50%	Very slow	"
2.84	9.44	8.16	0.09	0.36	"	"	0.62	3,550	No gas	No gas	48 hours	"
2.13	7.04	5.92	0.09	0.35	"	"	0.80	600	15%	40%	Slow	"
2.13	8.64	5.92	0.10	0.36	"	"	0.60	450	5%	50%	"	"
2.84	6.40	5.92	0.06	0.43	0.08	"	0.60	350	60%	90%	"	"
2.48	6.40	5.60	0.09	0.35	None.	"	1.30	350	No gas	No gas	Very slow	"
2.13	5.76	5.28	0.09	0.42	"	"	0.60	450	"	40%	14 hours	Yes
1.06			0.06	0.31	"	0.025	1.50	100	40%		Slow	No
2.48	7.68	6.08	0.08	0.36	"	None.	0.70	450	No gas	100%	Very slow	"
Trace.	7.20	5.92	0.06	0.39	0.16	"	0.60	250	5%		48 hours	"
0.71	6.56	6.56	0.05	0.36	0.12	"	0.70	2,200	No gas	5%	12 hours	"
1.06	7.20	6.56	0.06	0.36	None.	"	0.70	1,950	"	No gas	24 hours	"
2.48	7.36	7.20	0.05	0.36	"	"	0.70	150	"	"	No coag	"
1.78	7.20	6.72	0.07	0 28	"	"	0.72	Liquefied.	5%	"	12 hours	"
2.13	7.84	5.92	0.06	0.34	"	"	0.72	"	No gas	20%	Rapid	"
2.84	7.68	6.40	0.05	0.34	"	"	0.72	"	"	No gas	24 hours	"
1.42	7.36	5.76	0.05	0.31	0.04	"	0.52	"	"	"	Rapid	"
2.13	7.52	6.72	0.04	0.34	None.	"	0.50		"	"	28 hours	"
Trace.	6.64	5.52	0.07	0.38	"	"	0.62		40%	20%	Rapid	"
1.88	7.84	6.53	0.07	0.39	0.08	0.004	0.74					

TABLE III — *Mouth of*

Date.	Color.	Odor.	Sediment.	Temperature. Water	Temperature. Air	Solids. In solution	Solids. In suspension	Solids. Total	Loss on Ignition. Not filtered	Loss on Ignition. Filtered
1901										
Sept. 17	Dark Yellow	None	Clay			354	652	1006	82	30
" 24	"	Earthy	"	65°	83°	304	2506	2810	144	48
Oct. 10	"	None	"	62°	64°	296	1690	1986	116	22
" 14	"	"	"	60°	58°	296	934	1230	78	28
" 15	"	"	"	60°	70°	280	870	1150	68	24
" 16	"	"	"	61°	62°	296	792	1088	88	24
" 17	"	"	"	60°	59°	306	746	1052	82	12
" 21	"	"	"	62°	76°	360	1062	1422	86	24
" 22	"	"	"	64°	76°	384	1316	1700	92	32
" 23	"	"	"	64°	80°	330	1508	1838	170	42
" 24	"	"	"	64°	72°	334	1452	1786	152	32
" 28	"	"	"	62°	76°	320	948	1268	80	18
" 29	"	"	"	64°	76°	362	872	1234	86	28
" 30	"	"	"	64°	72°	346	916	1262	72	14
" 31	"	"	"	64°	64°	354	1070	1424	56	22
Nov. 4	"	"	"	54°	48°	340	1038	1378	66	24
" 5	"	"	"	50°	46°	352	1088	1440	102	28
" 6	"	"	"	52°	68°	332	968	1300	78	30
" 7	"	"	"	52°	50°	336	932	1268	72	16
" 8	"	"	"	50°	60°	350	878	1228	56	24
" 11	"	"	"	54°	74°	356	1784	2140	58	22
" 12	"	"	"	52°	50°	396	1800	2196	114	10
" 13	"	"	"	52°	60°	369	1617	1986	20	13
" 14	"	"	"	50°	50°	411	1611	2022	104	13
" 15	"	"	"	46°	40°	344	1352	1696	54	26
" 18	"	"	"	44°	67°	328	1060	1388	84	16
" 19	"	"	"	44°	46°	322	914	1236	72	20
" 20	"	"	"	42°	48°	328	786	1114	90	40
" 21	"	"	"	42°	50°	350	740	1090	62	34
" 22	"	"	"	44°	48°	326	684	1010	60	22
" 25	"	"	"	44°	48°	338	638	976	60	18
" 26	"	"	"	44°	48°	388	584	972	102	72
" 27	"	"	"	44°	44°	340	608	948	46	28
" 28	"	"	"	42°	42°	362	590	952	84	36
" 29	"	"	"	44°	58°	362	532	894	74	30
Dec. 2	"	"	"	44°	40°	382	506	888	108	38
" 3	"	"	"	44°	38°	350	498	848	76	34
" 5	"	"	"	40°	32°	372	434	806	88	46
" 6	"	"	"	40°	38°	362	448	810	52	36
" 9	"	"	"	40°	33°	368	398	766	82	40
" 10	"	"	"	38°	45°	362	356	718	76	42
" 11	"	"	"	40°	42°	374	356	730	72	46
" 12	"	"	"	42°	54°	356	356	712	72	52
	Means			51°	56°	346	948	1294	82	29

The Missouri River.

Chlorine	Oxygen absorbed: Not filtered	Oxygen absorbed: Filtered	Ammonia: Free	Ammonia: Albuminoid	Nitrogen: In nitrate	Nitrogen: In nitrite	Organic ammonia by Kjeldahl process	Colonies—per cc	Fermentation: 10 cc	Fermentation: 1 cc	Coagulation of milk	Indol produced
9.2	7.36	2.72	0.18	0.33	0.48	Trace	0.73	Plate Liquefied.	20%	20%	Rapid.	No
25.2	26.24	3.04	0.12	1.02	0.16	None	3.83	1,470	No gas	10%	"	"
10.3	12.00	3.68	0.04	0.92	0.14	"	2.32	.....	20%	No gas	Slow	"
12.0	8.96	1.92	0.06	0.55	0.22	"	1.32	.....	10%	10%	24 hours	"
10.6	9.76	4.32	0.08	0.61	0.36	"	1.52	1,100	90%	90%	"	"
12.8	8.48	2.56	0.05	0.50	0.14	Trace	1.32	4,700	90%	50%	"	"
11.4	8.16	3.84	0.15	0.61	0.14	"	1.32	16,200	No gas	No gas	Slow	"
20.6	30.08	15.04	0.14	0.72	0.16	"	1.32	18,600	5%	30%	Rapid	Yes
9.9	11.52	4.48	0.14	0.76	0.24	None	2.72	6,800	5%	50%	12 hours	"
12.1	15.04	3.20	0.10	0.92	0.24	"	2.72	6,100	No gas	15%	Rapid	No
11.4	21.44	2.88	0.11	0.87	0.16	"	2.22	6,200	5%	10%	20 hours	"
13.5	13.12	2.24	0.12	0.61	0.10	"	2.02	1,400	40%	50%	Slow	Yes
14.9	10.40	4.00	0.16	0.58	0.08	"	1.26	5,300	20%	No gas	"	No
17.8	9.92	2.64	0.04	0.65	0.20	"	1.52	11,800	10%	5%	"	"
14.2	12.48	3.04	0.07	0.68	0.16	"	1.26	4,250	No gas	No gas	24 hours	"
12.8	11.68	3.36	0.08	0.55	0.20	Trace	1.66	7,350	50%	20%	Rapid	Yes
14.9	8.64	2.88	0.13	0.56	0.28	"	1.82	.....	20%	50%	24 hours	"
12.8	9.44	2.56	0.08	0.46	Trace	"	1.42	18,100	10%	50%	Rapid	No
16.3	12.80	3.84	0.08	0.52	0.14	"	1.42	5,650	50%	10%	Slow	Yes
17.0	12.00	5.60	0.07	0.58	0.18	0.005	1.40	300	60%	40%	"	No
16.3	10.08	1.92	0.09	0.73	0.30	Trace	1.40	14,200	5%	5%	24 hours	"
29.1	11.36	2.08	0.13	0.72	0.10	"	2.20	9,950	No gas	10%	Rapid	Yes
24.8	10.56	2.08	0.07	0.74	0.10	None	2.10	10,600	"	No gas	16 hours	"
17.0	13.44	2.88	0.11	0.95	0.08	"	3.0	4,700	80%	80%	18 hours	"
22.7	12.64	2.72	0.12	0.97	0.28	Trace	2.20	2,400	60%	50%	Rapid	"
14.2	10.88	2.72	0.14	0.81	0.12	0.005	2.20	2,850	No gas	No gas	16 hours	No
12.8	9.92	2.24	0.13	0.71	0.14	0.005	2.04	10,700	50%	20%	12 hours	Yes
12.8	8.00	3.20	0.10	0.64	None	Trace	1.90	5,850	50%	40%	Rapid	"
7.1	8.80	2.72	0.10	0.61	"	"	1.50	Liquefied.	30%	50%	"	"
12.1	5.44	1.92	0.21	0.71	"	"	1.50	9,000	8.%	40%	14 hours	"
16.3	7.52	3.04	0.10	0.51	0.32	"	1.50	15,800	10%	50%	12 hours	"
9.2	6.72	4.32	0.10	0.58	None	None	1.10	9,400	5%	10%	Rapid	"
14.2	7.36	2.40	0.10	0.46	0.12	0.010	1.50	21,200	50%	40%	"	"
17.0	8.32	3.04	0.08	0.43	None	Trace	1.34	18,050	30%	60%	"	"
14.2	6.56	3.04	0.09	0.35	"	"	1.10	4,750	.....	40%	"	"
14.2	6.24	2.08	0.09	0.40	"	"	.90	1,350	.....	10%	Slow	No
6.4	6.08	2.08	0.11	0.39	"	None	1.10	Liquefied.	.....	30%	18 hours	Yes
16.3	5.28	2.72	0.10	0.35	0.10	"	1.12	"	20%	40%	Rapid.	"
14.2	6.56	2.56	0.09	0.28	0.14	"	1.12	.....	10%	10%	"	No
19.9	5.28	1.60	0.13	0.37	0.08	"	.72	.....	40%	50%	"	Yes
17.8	4.96	2.24	0.13	0.36	0.12	"	.72	.....	10%	10%	12 hours	No
11.4	6.24	3.52	0.11	0.30	None	"	.64	.....	20%	40%	14 hours	Yes
12.8	4.32	1.44	0.11	0.31	"	Trace	1.12	.....	10%	50%	Rapid	"
14.9	10.28	3.17	0.10	0.60	0.13	0.0006	1.61					

TABLE IV.—*Mouth of the*

Date.	Color.	Odor.	Sediment.	Temperature. Water	Temperature. Air	Solids. In solution	Solids. In suspension	Solids. Total	Loss on Ignition. Not filtered	Loss on Ignition. Filtered
1902.										
Feb. 24	None		Little	34°	50°	253.2	6.4	259.6	30.0	31.2
" 25	"		None	34°	55°	252.8	0.4	253.2	45.6	48.8
" 26	Yellowish		Little	34°	45°	252.0	30.0	282.0	62.4	56.0
" 27	"		"	34°	44°	239.2	16.4	255.6	42.0	46.4
*Mar. 3	Dark		Muddy	37°	40°	208.8	504.8	713.6	72 0	42.8
* " 4	"		"	34°	30°	224.0	429.6	653.6	90.0	62.0
" 5	"		"	34°	46°	264.0	206.0	470.0	70 4	47.6
" 6	"		"	34°	45°	224.0	335.6	559.6	68.0	42.0
" 10	"		"	39°	60°	228.0	161.6	389.6	90.0	38.0
" 11	"		"	42°	55°	198.8	180.8	379.6	90.0	42.4
" 13	"		"	42°	50°	199.2	180.8	380.0	85.2	58.4
" 17	"		"	44°	22°	214.0	503.6	717.6	84.0	38.8
" 18	"		"	41°	32°	228.0	252.8	480.8	59.2	40.8
	Means			37°	43°	229.7	216.0	445.7	68.4	45.8

TABLE V.—*The Mississippi River*

1902.										
Feb. 24	None		Nearly clear	34°	50°	202.0	10.8	212.8	49.6	62.0
" 25	"		"	34°	55°	205.2	8.4	213.6	54.8	47.2
" 26	"		Clear	34°	45°	196.0	1.6	197.6	44.0	47.2
" 27	"		"	34°	44°	195.2	5.6	200.8	53.2	57.2
Mar. 3	Little		Turbid	34°	40°	196.0	43.6	239.6	30.0	48.0
" 4	"		"	33°	30°	194.8	35.6	230.4	45.6	60.8
" 5	"		"	34°	40°	198.4	23.6	221.6	34.0	50.4
" 6	"		"	34°	45°	190.0	23.6	213.6	42.0	56.0
" 10	Dark		Muddy	36°	60°	178.0	173.6	351.6	64.0	52.0
" 11	"		"	38°	55°	158.0	247.6	405.6	46.0	24.0
" 13	"		"	40°	50°	165.6	342.4	508.0	64.0	73.6
" 17	"		"	42°	22°	174.0	200.0	374.0	60.6	13.0
	Means			35°	45°	187.8	93.0	280.8	48.9	49.3

TABLE VI.—*Mouth of*

1902.										
Mar. 10	Yellow		Muddy	44°	64°	338.0	1184.0	1522.0	134.0	54.0
" 11	"		"	46°	60°	320.4	1211.6	1532.0	148.4	16.8
* " 12	"		"	48°	48°	301.6	1384.8	1686.4	164.8	43.6
" 13	"		"	50°	60°	384.0	1217.6	1601.6	158.0	122.0
" 18	"		"	48°	42°	346.0	1600.0	1946.0	505.2	63.6
" 19	"		"	46°	50°	306.0	1303.6	1609.6	150.0	58.0
" 20	"		"	48°	64°	228.0	1182.0	1410.0	116.4	45.6
" 21	"		"	48°	52°	210.4	1238.4	1448.8	111.2	28.4
	Means			47.2°	55.2°	304.3	1290.2	1594.5	186.0	54.0

Illinois River—Grafton.

Chlorine	Oxygen absorbed: Not filtered	Oxygen absorbed: Filtered	Ammonia: Free	Ammonia: Albuminoid	Nitrogen: In nitrate	Nitrogen: In nitrite	Organic ammonia by Kjeldahl process	Colonies—per cc	Fermentation: 1/10 cc	Fermentation: 1 cc	Coagulation of milk	Indol produced
13.49	2.80	2.64	1.340	0.182	0.280	0.0	1.00	270	No gas	No gas	None....	No
14.91	2.88	2.80	0.874	0.194	0.240	0.0	1.00	40	"	"	"	"
15.62	3.84	3.20	1.512	0.216	0.320	0.0	0.80	180	10%	.....	24 hours.	"
13.49	3.04	2.96	1.500	0.168	0.200	Minute trace.	1.00	....	20%	20%	28 hours.	"
12.78	12.80	6.00	1.592	0.744	0.200	0.0	2.40	1,040	No gas	No gas	20 hours.	"
11.20	10.00	4.64	1.824	0.704	0.200	0.0	2.40	560	5%	"	36 hours.	"
12.07	10.00	5.20	1.684	0.484	0.200	0.0	1.60	Plate / Liqu'fi'd	30%	.....	Rapid...	Yes..
11.36	10.40	5.60	1.512	0.564	0.220	0.0	2.00	280	No gas	No gas	24 hours.	No
14.20	10.72	5.44	1.520	0.564	0.400	0.0	1.40	14,880	"	"	20 hours.	"
13.49	10.80	6.08	1.440	0.544	0.300	0.0	1.20	4.410	20%	20%	"	"
9.23	13.60	6.96	1.180	0.464	0.700	Trace.....	1.40	4,200	50%	50%	16 hours.	"
8.52	14.80	4.72	0.740	0.544	0.800	Minute trace.	1.60	550	30%	.....	24 hours.	"
12.07	10.80	7.20	0.760	0.504	1.120	0.04	1.20	820	100%	100%	18 hours.	Yes..
12.49	8.96	4.88	1.344	0.452	0.398	0.003	1.46					

Grafton—above mouth of Illinois.

2.13	4.64	4.48	0.140	0.106	0 160	0.0	1.20	60	No gas	No gas	None....	No
2.84	5.60	4.32	0.090	0.122	0.120	0.0	1.00	520	"	"	"	"
2.13	4.16	4.08	0.072	0.072	0.280	0.0	1.00	420	"	"	"	"
2.84	4.56	4.00	0.084	0.112	None.	Minute trace.	....	800	"	"	"	"
2.84	5.04	4.40	0.154	0.112	0.240	0.0	1.40	450	"	"	"	"
2.84	4.88	4.80	0.124	0.162	0.100	0.0	1.20	60	"	"	"	"
2.13	4.48	3.84	0.102	0.162	0.100	0.0	0.60	3,600	10%	.....	Rapid...	Yes..
2.48	6.24	4.40	0.106	0.162	0.100	0.0	0.60	120	No gas	.....	24 hours.	No
2.13	8.80	7.12	0 370	0.472	1.700	0.0	1.60	12,400	"	No gas	24 hours.	"
2.84	6.88	4.80	0.540	0.702	1.600	0.0	1.60	4,350	"	"	14 hours.	"
2.84	16.00	7.60	0.600	0 664	0.640	Trace	2.00	7,040	30%	30%	24 hours.	Yes..
1.42	13.76	4.24	0.544	0.544	0.640	0.03	1.40	420	50%	.....	24 hours.	"
2.45	7.09	4.84	0.244	0.283	0.473	0.003	1.24					

the Missouri River.

18.46	11.60	3.20	0.360	0.644	0.300	0.0	2.40	Plate Liquefied.	10%	.....	18 hours.	Yes..
17.75	13.20	6.24	0.240	0.524	0.240	0.0	2.40	1,440	35%	.....	16 hours.	No ..
19.88	15.60	4.88	0.232	0.664	0.300	Trace	2.80	680	No gas	.....	14 hours.	Yes..
17.75	17.20	5.20	0.344	0.684	0.400	"	3.60	42,160	80%	.....	12 hours	No ..
14.20	20.80	5.20	0.272	1.224	0.960	0.04	4.00	9,300	40%	.....	20 hours.	Yes..
11.36	22.40	4.96	0.332	1.084	1.200	0.006	....	290	15%	.....	16 hours.	"
7.81	18.40	4.40	0.312	1.084	1.200	0.020	3.60	590	30%	20%	2u hours.	"
8.52	18.00	5.60	0.268	0.884	0.800	0.020	3.00	160	30%	30%	18 hours.	"
14.46	17.15	4.96	0.295	0.849	0.675	0.011	3.27					

For the purpose of comparison the mean chemical results are tabulated below, the values all being given in parts per million:

	Illinois Fall.	Mississippi Fall.	Missouri Fall	Illinois Spring.	Mississippi Spring.	Missouri Spring.
Solids in solution	229	145	346	230	188	304
Solids in suspension	32	38	948	216	93	1290
Loss on ignition, filtered	36	33	29	46	49	54
Loss on ignition, unfiltered	40	36	82	68	49	186
Chlorine	16.4	1.88	14.9	12.5	2.45	14.46
Oxygen absorbed, filtered	3.21	6.53	3.17	4.88	4.84	4.96
Oxygen absorbed, unfiltered	4.31	7.84	10 28	8.96	7.09	17.15
Free ammonia	0.238	0.07	0.10	1.344	0.244	0.295
Albuminoid ammonia	0.413	0.39	0.60	0.452	0.283	0.849
Nitrogen in nitrates	1.042	0.08	0.13	0.398	0.473	0.675
Nitrogen in nitrites	0.034	0.004	0.0006	0.003	0.003	0.011
Organic ammonia, Kjeldahl	0.81	0.74	1.61	1.46	1.24	3.27

Several things are immediately apparent from an inspection of the tables. It will be seen at once that in the Illinois river from the beginning of the work in September to the end of the Fall observations in December there is an irregular but gradual increase in the factors measuring the extent of organic contamination. It would appear that the oxidizing destruction of organic matter has not been as complete as in the preceding year just after the opening of the large canal. But another thing is also evident, and that is that the concentration of the mineral matters is also greater. The figures for chlorine in the Illinois are so high as to indicate a degree of dilution but little in excess of that which obtained before the Drainage Canal was opened. This may be accounted for in two ways. The flow through the canal was allowed to drop from 300,000 to about 25 ',000 cubic feet per minute which had some effect, but the important point is this, that because of the extreme dry weather of 1901 the flow from the tributaries was very small. An unusually large fraction of the water leaving the Illinois at Grafton was therefore Drainage Canal water, and the important element of dilution was accordingly not satisfied. The small volumes of water passing from the sluggish tributaries into the main stream were comparatively concentrated organic extracts in which oxidation was far from complete. It must be recalled, in addition, that the contamination from the Peoria and Pekin distillery cattle sheds is a factor not to be overlooked at this season of the year. It is not an easy matter to secure accurate data regarding the number of cattle fed at these places, but in the Fall and Winter months the number is always large enough to make this form of contamination of the highest importance in determining the character of the water in the lower river.

Somewhat similar conditions prevailed in the Missouri in the Fall of 1901. The river was unusually low and the organic contents correspondingly high. During August and the early part of September I had occasion to observe the river at several points between the mouth and Kansas City and noticed this bad condition. It will be seen that the chlorine in the Missouri is nearly as high as that in the Illinois which points to the same fact of small dilution. The organic matter in the Missouri is derived from sever

sources. The population and the stockyards industries of Kansas City, Omaha, and other prominent places, contribute a large share, as does Chicago to the Illinois, but aside from this an enormous amount of organic detritus of vegetable origin is washed into the tributaries and finally into the main stream from the peculiar soils through which the waters flow. The organic contents of the Missouri is even higher than that of the Illinois, and, all things considered, is of the same general character. The sluggish flow in the Missouri for the period under consideration, has this important consequence that it prolongs the time through which oxidation may take place, which is very desirable, especially in the colder months. It is evident that in the case of the Illinois river in the colder weather the flow is too rapid to permit of the fullest possible oxidation. The element of time is always of the first importance here, and with decrease in temperature more time must be allowed for the various stages in bacterial oxidation. The presence of the dams in the Illinois river is, therefore, a factor favoring the fuller oxidation of organic matter since these dams retard the flow of the water to some extent and prolong the contact of the decomposing substances with the oxidizing bacteria.

In each series of examinations new conditions are presented and in a measure new results are obtained. It is not always possible to offer a rational explanation for these results as we are still far from understanding the exact conditions for the most perfect bacterial oxidation. In studying the above figures for the Illinois we are impressed by the high values given for nitrogen in the nitrate form during the Fall months and with the high free ammonia during the Spring. In the first case the excess, as compared with the 1900 Summer results, is doubtless due to diminished dilution, but the high free ammonia of the Spring is a consequence of unfinished or retarded oxidation. In the work of the Spring of 1900 it was found that more of the nitrogen had been oxidized to the nitrate stage, but on the other hand, in the 1902 work we have less nitrogen remaining in the albuminoid ammonia condition. For the Fall months the total organic ammonia (Kjeldahl) and the albuminoid ammonia are nearly the same for the Illinois and the Mississippi, while for the Missouri both factors are very much higher. For the Spring the Mississippi exhibits the best organic condition, with the Missouri far worse than the Illinois.

In examining the results obtained in the bacterial tests it will be noticed that the Illinois and Mississippi are much nearer alike than are the Illinois and Missouri. The bacterial count is at best a somewhat uncertain datum, but it will be remembered that these waters were taken under the same conditions, packed in the same way and that they reached Chicago with the same delay always. The results must have, therefore, some comparative value. In the mean the count for the Missouri river is very much higher than for the Illinois or the Mississippi, and the evidence from the coagulation of milk and the formation of indol is strong in showing the markedly greater contamination of the Missouri. Everything indicates that the organic matter present in this stream is in a much less advanced stage of oxidation than is the case with the other two. As to the character of the bacterial organisms in the three cases I refer to the valuable observations of Professor Zeit in his report.

It is now almost universally recognized and admitted that the self-purification of a stream is largely a matter of successive bacterial oxidations and reductions. The question naturally suggests itself: To what extent may this be controlled or hastened on the large scale. It is well known what may be done in the bacterial purification of volumes of sewage, not too large, by the septic tank and contact bed processes, but the sanitarian would hesitate before attempting to apply analogous processes to the treatment of a large river like the Illinois. Yet I believe that something of this character will be undertaken, and probably in the not very distant future. What is taking place in the pool between Peoria and Pekin is a suggestive object lesson, and what is there done by nature, I believe may be duplicated or controlled by art. The conditions which there prevail make this stretch of the river below the cattle sheds of the Peoria distilleries a great septic tank in which by the aid of myriads of bacteria enormous quantities of organic matter are rapidly broken up and put into form for final oxidation. The flow is sluggish here and time is given for the desired changes. To apply this general process further it might be necessary to artificially widen the river and retard the flow at some point below Pekin, and in the basin thus formed to enrich the bacterial flora by greatly concentrated pure cultures of the necessary species to rapidly advance oxidation. It may naturally be urged that the efforts of nature towards self-purification cannot be improved upon except at an enormous and prohibitive outlay, but I cannot fully agree with this idea. At the present moment such an undertaking would be practically impossible because of our lack of knowledge of the specific bacteria which are most active under different conditions. But to obtain such knowledge is certainly not beyond our reach, and in general should be secured from characteristic cases as illustrated by the following figures. In the Summer of 1886 and in the Summer of 1899 examinations were made under conditions apparently identical of the water flowing in the old Illinois and Michigan Canal between Bridgeport and Lockport, a distance af 29 miles. The collections were made at the same place and were numerous enough to furnish fair averages. The more important analytical results, in parts per million, were these:

	1886.			1899.		
	Free Ammonia.	Alb. Ammonia.	Oxygen Consumed.	Free Ammonia.	Alb. Ammonia.	Oxygen Cousumed.
Bridgeport...	26.56	1.63	26.2	19.84	3.22	26.65
Lockport.....	12.73	.75	11.0	19.85	3.37	27.90

In the two cases the water passed through the 29 miles between the two stations at about the same rate, perhaps 40,000 cubic feet per minute, and the initial contaminations from city and stockyard sewage were approximately the same, yet in 1886 we had a very rapid oxidation while in 1899 no change was evident. Why the bacterial scavengers were so much more active in the one year than in the other can not now be explained, but the difference in activity was probably due to some simple conditions in the water which

closer chemical investigations could have disclosed. A difference in acidity or alkalinity or in the amount of gas works refuse present may have had much to do with the bacterial growth and activity. In 1886 when the destruction of organic matter was so rapid in the canal the rate was continued through the river, and at Peoria the water of the Illinois was practically pure and safely potable. Bacterial tests, made at the time, but not published, showed a remarkably small number of germs. This condition of relative purity was not approached at Peoria in 1899.

In any event something was lacking in one year which was present in the other, and before being able to undertake the large scale purification of a stream these conditions must be determined by searching bacterial and chemical tests. The nature of the organisms which are the most efficient when the greatest oxidation is attained, under certain conditions of water temperature and mineral content, may be determined by observations extended over a period of time, and I am of the opinion that such information may be applied to the correction of unfavorable conditions when the oxidation rate appears to drop.

What may be called the normal elements of the sewage as discharged into the canal, that is the household and stockyards waste matters, are practically constant. The increasing and variable element is the manufacturing waste and on the nature of this many of the variations in the bacterial activity doubtless depend. These conditions for the Illinois are worthy of a close study.

Yours, respectfully,

JOHN H. LONG.

Chicago, July 15, 1902.

POSTSCRIPT.

Since writing the above I have had an opportunity of making an examination of the Illinois river throughout its whole length and of learning certain facts independent of the results of chemical analysis. These facts have been gathered from the health officers of the several towns along the bank of the river; from boatmen, fishermen and others who have been familiar with the character of the stream for years. All the information thus obtainable goes to show a much improved condition of the river as a whole, and special improvement in the stretch between Henry and Peoria. The water appears, in general, cleaner in every respect, and in and above Peoria is even used for drinking purposes by hundreds or thousands of people. The reports of the health officer of Peoria show a practically complete absence of typhoid fever among the users of the river water in that city.

Immediately below Peoria and Pekin, on the other hand, there appears to be an increased defilement of the river, which undoubtedly finds its explanation in the fact that the more rapid flow hastens the water through the septic basin below the Peoria distilleries and thus gives less time for the oxidation processes which take place there. Under the old conditions a large amount of organic sediment collected in this part of the river and decomposed gradually. Now much of this is carried farther and may be noticed at times as far as Havana perhaps. The effect of this is, therefore, to retard the completion of oxidation and leave certain reactions to be car-

ried out in the lower portions of the river. Of course, exactly the same results could follow from the increased flow of perfectly clean water from Lake Michigan or from heavy rains, as the organic matter here in evidence is the slop refuse and cattle shed waste from the Peoria and Pekin distilleries. This matter is now hurried along instead of being allowed to settle or to accumulate in the form of islands of filth.

Below Beardstown the increased volume of water in the river has resulted in furnishing generally improved conditions, which are the subject of comment by the river people. The old stagnant stretches are no longer found, and nothing remains to suggest by appearance organic pollution. At the time of the present writing the river is unusually high and thousands of acres are covered by the overflow. This condition is not normal and does not favor rapid oxidation. But the large normal overflow area along the Illinois is sufficiently great to provide, in ordinary seasons, time and place for important oxidation and purification processes. This fact should be kept in mind if the river is to be considered as a source of potable water.

J. H. L.

April 25th, 1903.

Identification of Pathogenic and Sewage Bacteria Found in the Illinois, Mississippi and Missouri Rivers

By F. ROBERT ZEIT,

Professor of Bacteriology,

Northwestern University Medical School,

Chicago.

IDENTIFICATION OF PATHOGENIC AND SEWAGE BACTERIA FOUND IN THE ILLINOIS, MISSISSIPPI AND MISSOURI RIVERS.

BY F. ROBERT ZEIT,

PROFESSOR OF BACTERIOLOGY,

NORTHWESTERN UNIVERSITY MEDICAL SCHOOL,
CHICAGO.

DR. JAS. A. EGAN, *Secretary of the Illinois State Board of Health:*

DEAR SIR:—A comparative examination for pathogenic bacteria found in the waters of the Illinois River at its mouth (Grafton, Illinois), the Mississippi River just above the point of entrance of the Illinois, and the Missouri River (a short distance above its junction with the Mississippi) during th months of October, November and December, 1901, and February and March, 1902, reveals the significant fact that during these months the Mississippi and Missouri Rivers contained more pathogenic and sewage bacteria than the Illinois River.

My former report showed that bacterial self-purification of the Illinois River begins below Morris and is practically complete between Henry and Upper Peoria and any marked pollution found at Grafton must be due to other causes than the drainage canal. The results of the present examination only tend to strengthen the views expressed in my former report.

I have tabulated the results of the bacteriological investigation and the bacteria which have been identified.

In accordonce with your request to examine only for pathogenic bacteria, no attempt has been made to establish the complete bacteriological flora of these waters but I have identified nearly all the bacteria grown on our Agar plates.

The water samples received by Prof. J. H. Long were plated out on Agar and Glycerine Agar and grown in the incubator (37°C) for ten days, during which time they were under observation, Control plates were made in all cases.

Pure cultures were made on different culture media whenever necessary for purposes of identification and in a number of instances the pathogenic effect of suspicious cultures was tested by intraperitoneal inoculation of Guinea pigs.

The number of water specimens examined is:

Illinios River, 38.

Mississippi River, 37.

Missouri River, 36.

The Agar plates grown at 37°C of the Illinois River water near Grafton remained sterile six times: Nov. 11, 12, 21, 26, 30 and Dec. 6. All the plates of the Mississippi and Missouri Rivers showed growths.

Of the bacteria identified the following were found most frequently:

	NUMBER OF TIMES FOUND:		
	ILLINOIS	MISSISSIPPI	MISSOURI
Bac. Coli Communis	13	19	26
Proteus Vulgaris	6	7	21
Bac. Mycoides	11	15	12
Bac. Mesentericus	11	19	14
Bac. Megat-rium	6	11	9
Bac Subtilis	17	15	13
Bac. Liquidus	4	6	2
Bac. Enteritidis	1	3	4
Bac. Acidi Lactici	2	0	4
Mic. Candicans	1	4	11

A number of other bacteria have been identified and are given in the following tables under "Other Micro-organisms."

During the early spring many of the water specimens from all three rivers contained numerous spores of hyphomycetes, Mucor, Aspergillus and Oidium.

I. Tabulated List of Findings, Illinois River.

II. Tabulated List of Findings, Mississippi River.

III. Tabulated List of Findings, Missouri River.

Respectfully submitted,

Chicago, July 18, 1902. F. ROBERT ZEIT."

38 Water Specimens from Illinois River.

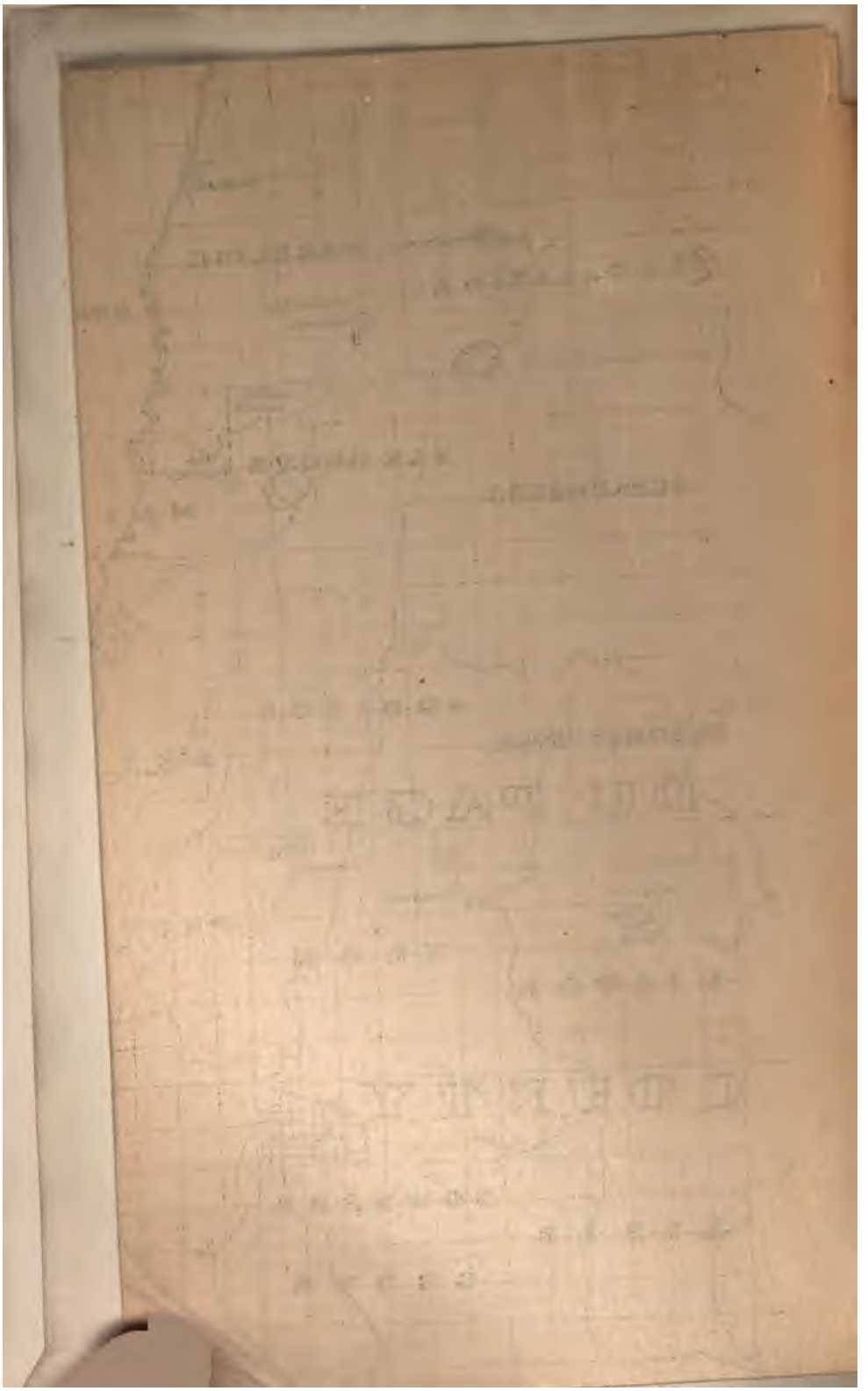
Date of Collection	Number	Bac. Coli Communis	Proteus Vulgaris	Bac. Mycoides	Bac. Mesentericus	Bac. Megaterium	Bac. Subtilis	Bac. Liquidus	Bac. Enteritidis	Mic. Candicans	Other Micro-organisms.
1901.											
Oct. 3	639			+						+	
" 8	643			+	+		+				Bac. striatus flavus
" 10	646			+	+		+				
" 14	649				+			+			
" 15	652	+				+	+				Mic. luteus
" 17	656										Bac. aurantiacus
" 21	659	+									Bac. aurantiacus
" 22	662	+	+			+	+	+	+		
" 28	667	+	+								Bac. acidi lactici
" 29	670	+	+			+	+	+			
" 31	674	+					+				
Nov. 4	677	+		+	+						
" 5	680						+				
" 11	688		Sterile.								
" 12	691		Sterile.								
" 14	695			+							Streptothrix
" 18	699	+		+							
" 21	706		Sterile.								
" 25	710					+	+				
" 26	713		Sterile.								
" 30	716		Sterile.								
Dec. 1	720				+		+				
" 2	723					+					
" 3	725	+		+							
" 5	728				+		+				
" 6	731		Sterile.								
" 9	733		Sterile.								
" 10	734	+		+			+				
" 11	740			+							
" 12	743				+						Mic. luteus
1902.											
Feb. 24	744	+					+				
" 25	746						+				
" 27	750						+				
Mar. 4	752		+		+		+	+			
" 5	754			+	+						
" 6	756		+		+		+				
" 7	758		+		+	+	+				Aspergillus and Mucor
" 11	760	+									Bac. acidi lactici

37 Water Specimens from Mississippi River.

Date of Collection	Number	Bac. Coli Communis	Proteus Vulgaris	Bac. Mycoides	Bac. Mesentericus	Bac. Megaterium	Bac. Subtilis	Bac. Liquidus	Bac. Enteritidis	Mic. Candicans	Other Micro-organisms.
1901.											
Oct. 8	642	....	+	....	+	....	+	....	....	....	Streptothrix
" 10	645	....	....	....	+	....	+	....	....	....	Sarc. aurantiaca
" 13	638	....	....	+	....	....	....	....	....	....	
" 14	648	....	....	....	....	+	+	....	....	....	
" 15	651	+	....	+	....	+	....	....	....	....	
" 17	655	+	....	+	+	....	....	+	+	....	
" 21	658	....	....	....	+	....	....	....	....	....	
" 22	661	....	....	+	....	....	....	....	....	....	
" 28	666	+	....	+	....	....	+	....	....	....	
" 29	669	....	....	+	....	+	....	....	....	....	
" 31	673	+	+	+	....	....	....	....	....	+	
Nov. 4	676	....	....	....	+	....	....	....	....	....	
" 5	679	+	....	....	....	+	+	....	....	....	
" 11	687	....	....	+	....	+	+	....	....	....	
" 12	690	....	....	+	....	....	+	....	....	....	
" 14	694	....	....	+	+	....	+	....	....	....	Bac. aurantiacus
" 18	698	....	....	....	+	....	....	....	....	....	
" 21	705	....	....	+	....	....	....	....	....	....	
" 25	709	....	....	....	....	+	+	....	....	....	
" 26	712	....	....	+	+	....	....	....	....	....	
" 28	716	....	....	+	+	....	....	....	....	....	
" 29	719	+	+	....	+	....	+	....	....	+	
Dec. 2	722	....	+	....	+	....	....	....	....	....	
" 5	727	+	....	+	+	....	+	....	+	....	
" 6	730	+	....	+	....	+	....	+	....	....	
" 9	732	+	....	....	+	+	....	....	....	....	
" 10	736	+	....	....	+	....	....	....	....	....	
" 12	742	....	....	....	+	....	....	....	....	....	
1902.											
Feb. 24	745	+	....	....	+	+	....	+	+	....	
" 25	747	+	....	....	+	....	....	....	....	....	
" 26	749	+	....	+	....	....	+	....	....	....	
" 27	751	+	....	....	....	....	....	+	....	....	
Mar. 3	753	+	....	....	+	....	+	....	....	....	Sarc. lutea
" 5	755	+	+	....	....	....	+	+	....	+	
" 6	757	+	+	....	....	+	+	+	....	....	
" 7	759	+	+	....	....	+	....	....	....	+	
" 11	761	+	....	....	....	....	+	+	....	....	Aspergillus and oidium

36 Water Specimens from Missouri River.

Date of Collection	Number	Bac. Coli Communis	Proteus Vulgaris.	Bac. Mycoides	Bac. Mesentericus	Bac. Megaterium	Bac. Subtilis	Bac. Liquidus	Bac. Enteritidis.	Mic. Candicans.	Other Micro-organisms.
1901.											
Oct. 10	644	....	.....	....	....	+	+	....	....	+	Bac. albus putidus; streptothrix.....
" 14	647	+	.....	....	+	+	+	....	....	....	Bac. albus putidus; sarc. aurantiaca.....
" 15	650	....	.....	....	+	....	+	....	....	....	.....
" 16	653	+	+	+	+	....	....	....	+	+	M. flavus liquefaciens .....
" 21	657	+	+	+	+	....	....	....	....	+	Bac. acidi lactici.....
" 23	663	+	.....	+	....	....	+	....	....	....	Mucor.....
" 24	664	+	.....	....	....	....	+	....	....	....	Micr. luteus..... .....
" 28	665	+	+	+	+	....	....	+	....	+	B. acidi lactici..... .....
" 29	668	+	.....	....	+	+	....	....	....	....	Sarc. aurantiaca ....
" 30	671	+	+	....	....	....	....	....	....	....	.....
" 31	672	+	.....	+	....	+	....	....	....	....	.....
Nov. 4	675	+	+	....	+	....	+	....	+	+	.....
" 5	678	....	.....	....	+	....	....	....	....	....	.....
" 6	681	+	+	+	....	+	....	....	....	+	.....
" 7	682	....	.....	....	....	....	....	....	....	....	Mucor.....
" 8	685	+	+	....	....	....	....	....	....	....	.....
" 11	686	....	.....	+	....	....	+	....	....	....	.....
" 12	689	....	.....	....	+	+	....	....	....	....	.....
" 13	692	+	.....	....	....	....	+	....	....	....	Bac. albus putidus.....
" 14	693	+	+	....	....	....	....	....	....	....	Aspergillus.....
" 15	696	....	.....	+	....	+	+	....	....	....	.....
" 18	697	+	.....	....	+	....	....	....	....	....	.....
" 21	704	+	+	+	....	+	....	....	+	+	Bac. acidi lactici; oidium.....
" 22	707	....	+	....	+	....	....	....	....	....	.....
" 25	708	+	.....	....	....	....	....	....	....	....	Bac. striatus flavus.....
" 26	711	+	+	....	....	....	....	....	....	....	.....
" 28	715	+	+	....	....	....	....	....	....	....	.....
" 29	718	+	+	....	+	....	....	....	....	....	.....
Dec. 2	721	....	+	....	....	....	....	....	....	....	.....
" 3	724	....	+	....	....	....	....	....	....	....	.....
" 5	726	+	+	+	....	+	....	....	....	....	.....
" 6	729	+	+	+	+	....	+	....	+	+	B. acidi lactici..... .....
" 9	734	+	+	....	+	....	+	....	....	+	....
" 11	738	+	+	....	....	....	+	....	....	+	.....
" 12	741	+	+	....	....	....	....	....	....	....	.....
1902.											
Mar. 11	762	+	+	+	....	....	+	....	....	+	Aspergillus, mucor, oidium .....



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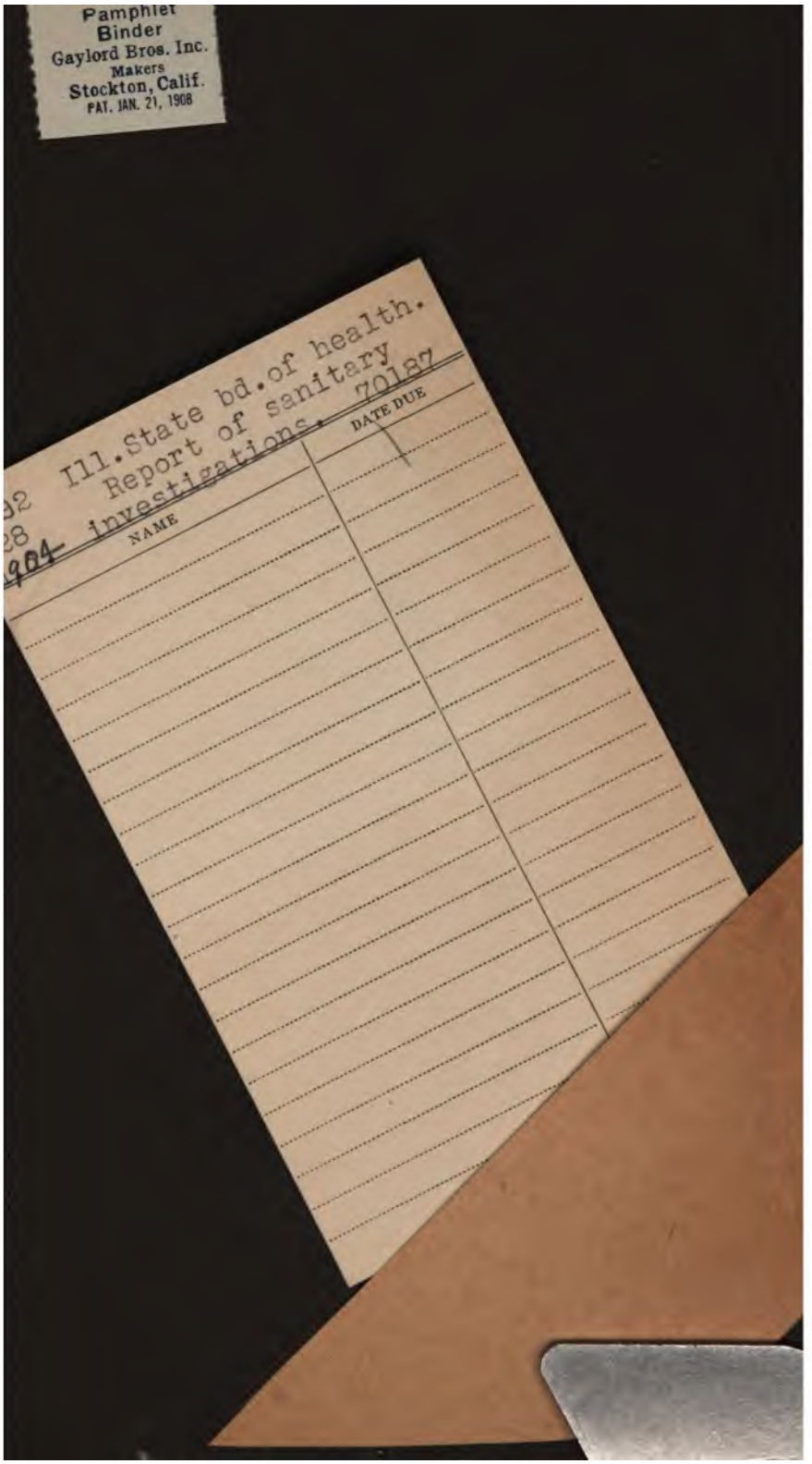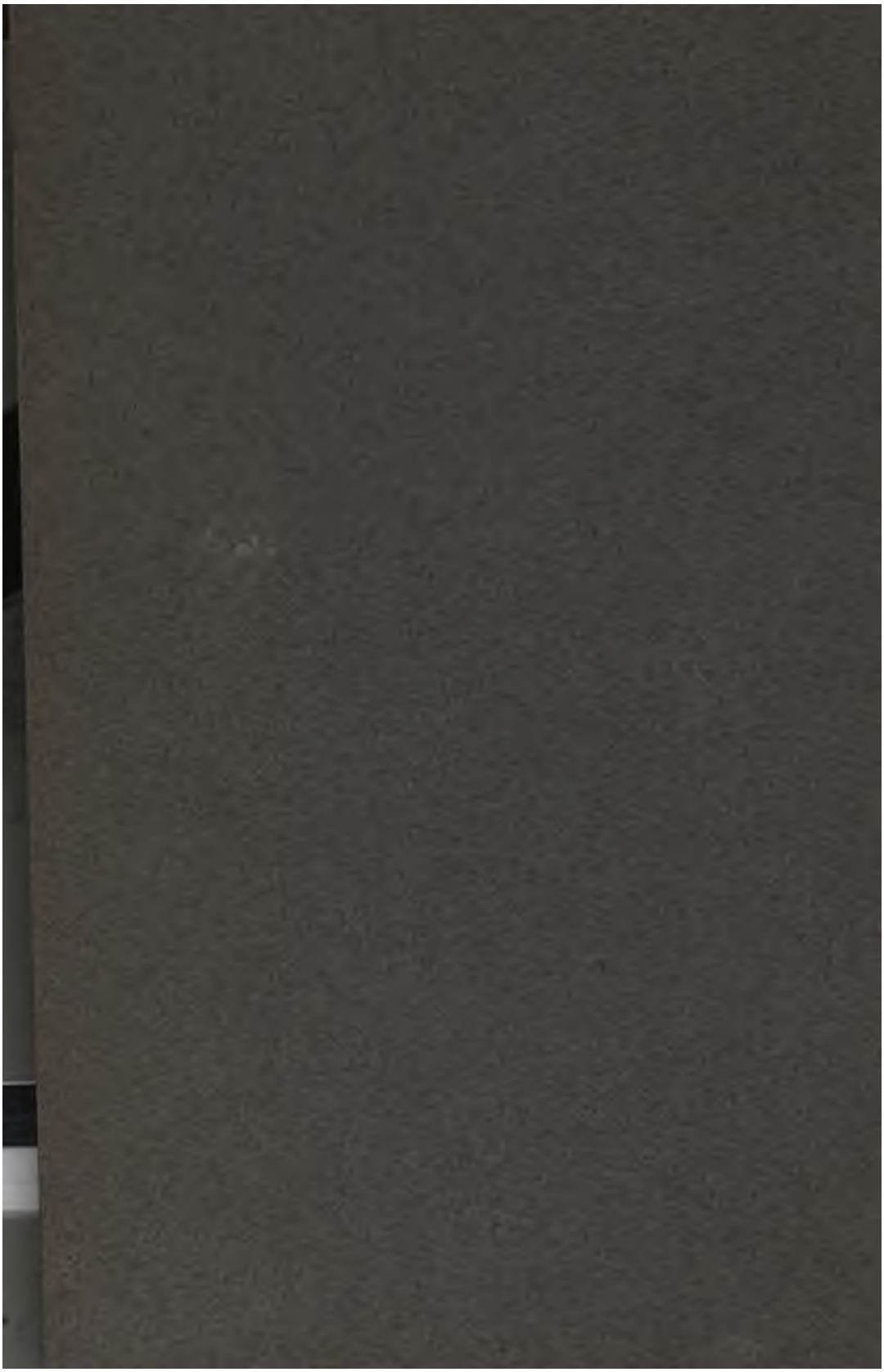
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